Seeding Diversity:
Enhancing farmers' access to crop varieties and quality planting materials in Uganda's seed systems

CROP TRUST

NMBU

Alliance Bioversity & CIAT

Norad

NARO PLANT GENETIC RESOURCES CENTRE (PGRC)

The Norwegian University of Life Sciences (NMBU)
Postboks 5003, 1432 Ås
Telefon: 67 23 00 00
E-mail: post@nmbu.no
Organisasjonsnummer: 969159570
www.nmbu.no

ISBN: 978-82-575-2186-8

Disclaimers

Suggested citation

Mulesa, T. H., Otieno, G., Dalle, S.P., Mohamed, M.D., and Westengen, O.T., 2024. Seeding Diversity: Enhancing farmers' access to crop varieties and quality planting materials in Uganda's seed systems. Crop Trust and Norwegian University of Life Sciences.

Authors

Teshome Hunduma Mulesa[1], Gloria Otieno[2], Sarah Paule Dalle[1], Mubiru Daudi Mohamed[2], and Ola Tveitereid Westengen[1].

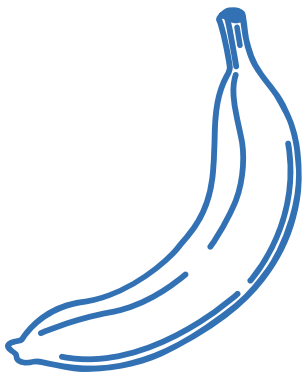
[1]Department of International Environment and Development Studies, Faculty of Landscape and Society, Norwegian University of Life Sciences, 1430 Ås, Norway.

[2]Alliance of Bioversity International and CIAT, Kampala 24384, Uganda.

Design and Layout

Natalia Rodriguez

Seeding Diversity: Enhancing farmers' access to crop varieties and quality planting materials in Uganda's seed systems



Contents

List of Acronyms

ABC	Alliance Bioversity International and CIAT
BOLD	Biodiversity for Opportunities, Livelihoods and Development
CGIAR	Consultative Group for International Agricultural Research
CSB	Community seed bank
GCDT	Global Crop Diversity Trust
EGS	Early generation seeds
FGDs	Focus group discussions
KIIs	Key informant interviews
LSB	Local seed business
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
NAADS	National Agricultural Advisory Services
NARO	National Agricultural Organization
NaCRRI	National Crops Resources Research Institute
NGOs	Non-governmental organizations
NMBU	Norwegian University of Life Sciences
NORAD	Norwegian Agency for Development Cooperation
NPGRC	National Plant Genetic Resource Center
NSCS	National Seed Certification Service
OWC	Operation Wealth Creation
PPB/VS	Participatory plant breeding and variety selection
PVPA	Plant Variety Protection Act
QDS	Quality declared seeds
ZARDI	Zonal Agricultural Research and Development Institute

List of Figures

List of Tables

Acknowledgments

We thank the Norwegian Agency for Development Cooperation (NORAD) for funding this study under the Biodiversity for Opportunities, Livelihoods and Development (BOLD) initiative. BOLD is a 10-year project aimed at enhancing food and nutrition security globally by promoting the conservation and utilization of crop diversity. The Global Crop Diversity Trust (GCDT) manages the project in collaboration with national and international genebanks and research and development organizations worldwide.

Our most profound appreciation goes to the farmers in the study areas of Hoima, Kabaale, Sheema, and Soroti districts in Uganda. We thank them for their cooperation, kindness, and invaluable insights shared during the Focus Group Discussions (FGDs).

We also thank the representatives from various public, community, non-governmental, and private seed sector stakeholders and national institutions for participating in the Key Informant Interviews (KIIs). Their experiences and perspectives on Ugandan seed systems greatly enriched our understanding.

Special thanks to our dedicated enumerators – Sylvia Mugisha, Anna Sofia Asingo, Jasper Ahumuza, and Osbert Arinda - for their tireless efforts and commitment during the FGDs and KIIs, ensuring high-quality data collection.

We acknowledge the support of Dr. John Wasswa Mulumba, Ms. Eva Zaake, Joyce Adokorach from the National Plant Genetic Resources Centre (NPGRC), and Ms. Sharon Kembabazi from Makerere University throughout the inception workshop, roundtable meetings, and data collection phase. Their assistance was invaluable, including facilitating connections with specialists from the Ministry of Agriculture, Animal Industry, and Fisheries (MAAIF) and the National Agricultural Research Organization (NARO).

We thank Brenda Atimango from Alliance Bioversity International and CIAT for her logistical support during fieldwork, workshop launches, and roundtable meetings.

Ana Catarina Mendes Leite created a detailed map of Uganda and its study areas skillfully. Natalia Rodriguez contributed by designing an aesthetically pleasing layout and helping with graphic design and technical editing, significantly improving the research report's presentation and quality. We sincerely thank both Ana and Natalia for their valuable contributions.

Foreword

This study characterizes the Ugandan seed systems by assessing the roles, activities, and performance of both formal and informal seed system actors and the factors influencing farmers' access to the diversity of crop species and varieties in Uganda. The study identifies strengths and weaknesses in the seed system's functioning and analyzes how governance, institutional, technical, and other factors influence it. The study also seeks to understand different actors' perspectives on seed system development and how they vary. On the ground, this study maps the seed sources farmers utilize, identifies seed security challenges they encounter, and explores how these challenges are influenced by cultural, political, climate, market, and other factors. By understanding farmers' preferences and needs, we aim to provide insights into how the seed system can better meet local-level requirements. Based on these analyses, the study proposes practical ways to connect diversity holders such as genebanks, breeding programs, and community-based actors with downstream seed system actors and ultimately to enhance farmers' access to crop diversity to meet their needs and preferences.

This research report presents the findings of a study conducted under the Biodiversity for Opportunities, Livelihoods, and Development (BOLD) project, a ten-year initiative funded by the government of Norway. The project aims to strengthen food and nutrition security by preserving and utilizing crop diversity in genebanks. The study is a deliverable of the Genebanks and Seed Systems work package, led by NMBU in collaboration with the Alliance Bioversity International and CIAT (ABC) Hub in Uganda and the Ugandan National Plant Genetic Resource Center (NPGRC). This work package identifies and tests sustainable pathways to improve farmers' access to crop diversity.

Executive Summary

Ensuring food and livelihood security in rural areas relies heavily on crop diversity, yet farmers often struggle to access suitable seeds and planting materials. This study maps and characterizes Uganda's seed systems to identify approaches to enhance farmers' access to seeds of well-adapted and preferred varieties. Based on qualitative data from key informant interviews (KIIs) with a range of actors involved in the seed system, focus group discussions (FGDs) with women and men farmers, document analysis, and stakeholder workshops, this report examines the country's seed systems from the local to the national level focusing on key seed system functions and outcomes.

Crop diversity, variety development, and varietal suitability

A tremendous crop diversity underpins Ugandan seed systems. This is visible from the local case studies as well as from the national seed system analysis. In eight key food and livelihood crops identified by FGD participants in four study sites, i.e., Hoima, Soroti, Sheema, and Kabaale districts, farmers identified 246 cultivated varieties. Bananas, beans, and cassava exhibited the highest intra-specific diversity and were found to be crucial for household food security. Maize, sorghum, and Irish potatoes displayed slightly lower diversity. The public genebank, NPGRC, is mandated to conserve and make crop diversity available to users. Conserved germplasm is utilized by formal, intermediate, and farmers' seed system actors as a source of diversity. The formal systems' research organizations NARO/ZARDIs, in collaboration with international research organizations like CGIAR centers, have focused on major legumes (such as beans) and cereals like maize and rice. Also, private actors have focused on the major staples and vegetables in a profitable seed market. In comparison, much less investment and research has been directed at breeding crops like sorghum, sesame, millets, and traditional vegetables.

Farmers grow popular crop varieties with desired characteristics, such as high yield and traits related to market demand, including grain color, size, and culinary versatility. These traits help many households and communities continue cultivating and preserving high-yielding crop varieties. However, this study also shows that many landraces and deteriorating improved varieties are being abandoned locally and declining, mainly because of climate change impacts, low market demand, poor adaptation to growing conditions, and susceptibility to pests and diseases. There is a complex relationship between positive and negative traits, which affects the abundance and distribution of essential crop varieties. While some varieties are praised for their desirable qualities related to farming practices (e.g., crop rotation and intercropping), cooking, and market demand, others are being abandoned in the communities due to inherent limitations such as low yield, susceptibility to environmental stresses, and inadequate market demand.

As the crop diversity cultivated historically declines in farmers' fields, farmers face challenges in accessing new varieties while experiencing conflicting messages from the NGOs and the extension service about new cultivars/varieties, landraces, and farmers' varieties. It is essential to improve current conservation efforts that aim to combine on-farm management with ex-situ conservation practices. This can be done by connecting the national genebank, community seed banks, and breeding programs and coordinating the work of NGOs and agricultural extension agents. These efforts should include demand-driven and decentralized breeding programs to create resilient and market-oriented crop varieties. Additionally, there is a need to assess how to disseminate improved varieties currently sitting on the shelf, further promote those that have seen some success, and reintroduce lost diversity. By supporting these combined strategies for conservation and improvement of crop genetic resources, actors can promote sustainable farming

practices such as cultivating diverse crop species for crop rotation, soil fertilization, and intercropping that align with local contexts and the changing needs of farmers. This strategic intervention can help reduce the risks associated with agricultural uniformity, increase agricultural resilience, and improve food security in the study areas.

Seed production, availability, and quality

Seed production in Uganda involves various actors and seed types crucial for crop sustainability. About 32 registered seed companies in Uganda contribute to formal seed supply. They focus on producing certified seeds of hybrid maize, hybrid vegetables, OPV maize, and beans. They enhance seed availability through both local production in Uganda and seed importation. The government's Operation Wealth Creation program has been collaborating with the National Agricultural Organization (NARO) and associated Zonal Agricultural Research and Development Institutes (ZARDIs) and Uganda Prisons Limited to produce limited certified seeds of improved varieties.

Local certified seed production through government input support programs and by private companies is greatly constraint by high prevalence of pests and diseases. Seed companies also encounter challenges like high taxation, lack of access to credit, and poor infrastructure for certified seed production. They also face limitations due to insufficient implementation of seed laws and regulations, e.g., breeders' rights or plant variety protection, access to EGS, field inspection, and quality control services. Coordination among seed system actors is lacking, exacerbating seed production challenges.

In the farmers' seed systems, farmers are the primary actors and primarily produce and save seeds of landrace crop varieties and improved open-pollinated varieties (OPV) for use in Uganda. Dependence on household-produced and farm-saved planting materials like sweet potato vines, cassava cuttings, and banana suckers is nearly 100 %. Local Seed Businesses (LSBs) and Community Seed Banks (CSBs) are emerging as key intermediaries, linking formal and informal seed systems. They incorporate local varieties from genebanks and farming communities and improved varieties from public breeding programs into their seed production efforts. The rise of quality declared seed (QDS) produced by LSBs has enhanced the quality of locally available seed, particularly for non-hybrid varieties and minor crops.

At the same time, seed production by informal/intermediate seed system actors faces several challenges. Households that save some of their harvest for planting the next season often lack the necessary knowledge, skills, and infrastructure to preserve high-quality seeds and other planting materials. They also cannot produce all crops and meet their demand for planting material for the next season when crop production requires crop rotation or adjustment due to climatic variability, such as late rain. LSBs face sustainability challenges in QDS production due to unreliable external funding and lack of government budget support. All organized seed producers struggle with issues like decreasing land size, soil infertility, erratic weather patterns, and pest and disease pressures. However, local seed producers, such as LSBs and CSBs, struggle to secure land, foundation seeds – especially for root, tuber, and banana (RTB) crops – and other inputs than well-funded government and private sector programs. Overall, there is a notable deficiency in skills and capacity for post-harvest handling, storage, and disease management, underscoring the need for targeted interventions to improve seed quality among community-based groups and households that produce and store most of the seeds farmers use in Uganda.

Within the formal seed system, the NARO and its ZARDIs are sources of EGS, such as foundation seeds for all certified and QDS producers in Uganda. However, these institutions face challenges in producing and distributing sufficient quantities of EGS due to funding constraints, shortage of breeder seeds, inadequate human resources, limited infrastructure such as irrigation facilities for off-season multiplication, and poor coordination among actors. This situation has improved in the last two years with NARO's introduction of variety licensing, which aims to address the shortage of EGS. Still, transparency and equitable access to EGS remain concerns, especially among seed companies that produce certified seeds.

Examining the availability of seeds, an essential component of seed security, we found significant shortages of seeds for many crops in the study locations. Farmers often struggle to obtain diverse varieties in sufficient quantities for optimal crop production. Improved varieties of vegetatively propagated planting materials like banana suckers, cassava cuttings, and other RTB planting materials are nearly unavailable in adequate amounts from specialized producers, and availability is mainly limited to local planting materials from their own production and social networks. Although seed companies and agrodealers supply seeds of diverse cereal and legume crops, availability from these sources fluctuates and falls short of meeting demand. Farmers purchase grains from the local market for legumes and cereals, especially for beans to plant if they do not have enough at home or cannot find what they need through their social networks. Nevertheless, this often means they have to compromise on quality. While LSBs show promise in providing an increasing quantity of quality-declared seeds, they require support to improve capacity and reliability.

The quality of seeds can vary greatly depending on their source. Farmers participating in FGDs rated the quality of seeds they saved themselves very highly because they were confident in the stability and germination rates, although there were instances where there were varietal mix-ups within and between species. The quality of seeds obtained through social networks and research stations was also rated highly, although there were some issues with reliability and varietal impurities at times. In contrast, seeds from agrodealers, local markets, and government schemes were generally rated lower in quality, with reported issues including low germination rates and variety impurity, which farmers often link to counterfeit seeds. CSBs, research stations, and LSBs were rated higher in seed quality than commercial sources, highlighting farmers' positive perception of community-based seed production and supply and their increasing importance. FGD participants praised CSB groups' careful sorting, labeling, and storage practices, ensuring high-quality seeds. Farmers said the quality of the trial material seeds received from research stations was the best.

Despite farmers' high rating of farm-saved seed, it is important to note that the seed quality often suffers due to poor post-harvest handling and storage practices, which raises concerns about the spread of diseases and pests, especially in RTB crops. This discourages farmers from using off-farm sources for RTB planting materials to avoid crop loss. Stakeholders such as breeders, seed regulatory agencies, and extension officers are worried about farm-saved seeds' genetic vigor, seed viability, and climate resilience. For instance, breeders expressed skepticism about farmers' perceptions of seed quality and trust, noting inconsistencies in farmers' preferences for free government seeds over certified seeds from agrodealers and highlighting a general mistrust and lack of information about the benefits of certified seeds. Poor seed storage facilities and variety sorting practices were identified as significant concerns across all study sites, indicating a need for improvement in seed quality management at the household level.

Overall, resolving the above challenges in seed production from all sources, including informal, intermediate, and formal, is crucial to ensuring consistent and adequate availability of quality seeds and other planting materials for farmers in Uganda.

Seed sources, distribution, and access

The distribution of seeds in Uganda involves various channels and actors, including formal, informal, and intermediary seed sources. Due to high costs, limited availability, and untimely supply of certified seeds, farm-saved seeds are prevalent in Uganda. Additionally, our study shows that uncertainties about off-farm seed quality and lack of information about the traits of certified seeds due to insufficient extension services contribute to farm-saved seeds' prevalence.

Our local research confirms that social networks and local markets are the most common sources of off-farm seeds after farm-saved seeds. Farmers prefer using farm-saved RTB planting materials and obtaining them from trusted sources, such as family or friends, when they do not have enough at home to avoid the risk of disease contamination. Social seed networks are the most widely used source for most of

the key crops in the study districts because they offer the highest accessibility due to diverse transaction methods and proximity to farmers. Seed loans from CSBs and purchases of QDS from LSB members and local stores are becoming increasingly popular due to affordability and proximity. Local markets are widely used to obtain grain, particularly legumes (beans) and cereal crops, for planting. Although some private seed companies and breeders have expressed concerns about market distortions resulting from the emergence of CSBs and LSBs, our study has found that these local institutions play a crucial role in providing farmers with high-quality and diverse seeds that are both locally accessible and affordable. However, they face challenges reaching scale to meet farmers' demand for their seeds and sustaining their operation due to defaulters, theft, limited markets, and lack of government budget support. Private seed companies face taxation, currency shortages, and limited demand for certified seeds, impacting their relationships with buyers (agrodealers and buyer institutions) and farmers.

Accessing seeds presents a complex challenge in Uganda, influenced by factors such as the high price, availability, and awareness of available options. Although cash-based transactions are common, especially from agrodealers and local markets, seed access varies based on location and crop type. Social networks are essential in accessing planting materials, providing various means of access such as gifts, loans, and barter trade. Bulky planting materials like banana suckers and cassava cuttings face logistical barriers in transportation, impeding access from remote places or other communities. Although CSBs offer accessible seeds through loans or gifts, limitations exist for non-members and specific crops. Research stations inject new varieties for trial, adding to the formal seed supply. However, their mandate is not to produce and distribute seeds regularly, and seed availability and reliability from them are limited. The government and humanitarian organizations provide relief during crises but are not always there to address sustainable seed access.

Numerous marginalized groups encounter significant obstacles in obtaining seeds. These groups include poor farmers, women, youth, elderly individuals, and those with disabilities. Financially constrained farmers face challenges in accessing certified seeds from agrodealers and LSBs due to their cost, while the elderly and people with disabilities experience challenges in traveling to obtain seeds and in participating in labor activities. Individuals struggling with alcohol addiction, casual workers, and youth generally lack the resources to access seeds. Additionally, youth face challenges due to limited land availability and negative societal perceptions categorizing them as lazy. Widows often have to handle land disputes, and women generally face financial constraints.

To address these issues, the FGD participants proposed various strategies, such as providing youth initiatives for land leasing, offering seed aid for older individuals, creating job opportunities for women, and extending community and government support for people with disabilities and landless individuals. These strategies aim to ensure equitable access to seeds for all. Coordinated efforts are necessary to improve seed access from available sources for all farmers nationwide.

Seed governance

Although Uganda's pluralistic policy approaches in variety development, seed production, and seed distribution have shown promise, the implementation of the national seed policy (1), the seed and plant variety protection laws (2, 3), and related seed regulations (4-6) is yet to be fully implemented (7). Despite the development of regulatory frameworks, such as the national biodiversity regulations (8), issues arise in their practical application, particularly regarding access permits and benefit-sharing agreements, as institutional mandates have yet to be clarified. Moreover, despite national policy recognizing the importance of farmer-developed varieties and registration for marketing, the lack of support from agricultural scientists in formal research and development and the absence of clear guidelines for registering these varieties hindered community-based actors from producing and marketing seeds locally, where these resources are well-adapted.

There are challenges with plant variety registration, release procedures, and intellectual property rights management. Some actors claimed there are

conflicts of interest in the plant variety registration and release processes. Concerns were expressed about the impartiality of institutions responsible for conducting national performance tests, DUS tests, and seed certification. Despite Uganda's relatively low DUS testing and variety registration fees, as stated in the seed and plant regulations, breeders and the Ugandan Seed Trade Association (USTA) have expressed concerns about the practices of the regulatory agencies and the involvement of NARO. They claim that these have resulted in expensive fees and regulatory complexities, which they see as barriers for private sector stakeholders. These challenges allegedly impede innovation and investment in the plant breeding industry. In addition, there are inconsistencies in the regulations, such as those related to implementing the COMESA Seed Trade Harmonization Regulations. For instance, Uganda requires national performance trials of varieties listed on the Common Market for Eastern and Southern Africa (COMESA) variety catalogue before being released for seed production. This makes it difficult for private seed companies and breeders to market and distribute new varieties, causing uncertainty. According to USTA, implementing breeders' rights lags in Uganda and should be a priority to encourage more investment in plant breeding.

The governance of seed inspection, quality control, certification, and marketing in Uganda is also complicated. Although the government decentralized seed inspection services to implement the 2018 seed policy, significant gaps persist in operationalizing these measures, stemming from budgetary constraints, inadequate infrastructure, and systemic inefficiencies. Insufficient resources allocated to essential elements such as seed inspectors, seed testing laboratories, transportation facilities, and equipment hinder the smooth functioning of seed inspection and certification processes, contributing to non-transparent practices such as corruption and favoritism. For instance, seed companies and other QDS producers currently incur expenses for seed inspections that result in inefficiencies.

Recent initiatives show a renewed commitment to addressing governance issues within the formal seed system. These initiatives include licensing public varieties to seed companies and training and accrediting new seed inspectors. The recognition of QDS as a seed class by the national seed policy and the introduction of QDS regulation is a step toward formalizing community-based seed systems and enhancing seed quality. However, the practical implementation of this faces obstacles due to a lack of public budgetary support, limited technical capacity, and reliance on support from external actors, which is unsustainable in the long run. Addressing these governance challenges requires collaborative action and strategic interventions to better coordinate and promote transparency, accountability, and inclusivity within the seed sector.

Recommendations

Based on the study results and stakeholder consultation, three recommendations for short- to long-term interventions to increase farmers' access to suitable varieties and quality seeds in Uganda are proposed.

I. Increasing seed availability and access: In the short to medium term, we recommend strengthening community-based and market-oriented seed production and distribution to increase farmers' access to quality planting materials, including improved varieties and landraces preferred by farmers. In the short term, initiatives could strengthen the seed production and dissemination activities of LSBs run by individual and organized groups of farmers, certified RTB nurseries and mother RTB gardens run by enterprises, and CSBs that have begun producing QDS. In the medium term, this could pave the way for developing a multistakeholder seed security innovation platform to provide long-term support for improving seed availability and access.

II. Enhancing varietal suitability: In the medium to long term, efforts are needed to strengthen the conservation of existing crop varieties, especially those endangered or underutilized, and develop new varieties using participatory, demand-driven approaches. Specific suggestions include enhancing coordination among existing institutions through the establishment of a

functional platform for ex-situ conservation, germplasm multiplication, and characterization, and enhancing participatory evaluation of breeding lines sourced from public research institutions, characterized genebank materials, released improved varieties, and CSB materials with superior genotypes.

III. Improve seed-related policies, regulations, and directives: To address the gaps identified in the seed governance system, the establishment of an annual or biannual seed governance dialogue forum is proposed to exchange information among network members and pertinent stakeholders regarding government policies, strategies, legal provisions, restrictions, develop proposals for needed reforms and to promote the full implementation of the 2018 national seed policy.

1 INTRODUCTION

1.1 Background

Uganda's agricultural sector accounted for 24% of its GDP and 35% of its total exports. It is the primary employer, with 68% of the population engaged in farming activities in 2022/2023 (9). Smallholder agriculture makes up about 95% of farming activities in the agricultural sector. Despite population growth, the agricultural sector has not experienced a similar increase in growth (9-11). This sector faces various risks, such as land degradation (41%), inconsistent rainfall patterns, frequent hailstorms, reduced rainfall, longer dry spells, fluctuations in temperature, and increased disease and pest outbreaks. These challenges significantly impact smallholder farmers' agricultural production and rural communities' livelihoods (9, 12, 13).

In the past, Uganda's seed policies and programs primarily focused on formal seed system development. Despite recent policies promoting pluralistic seed system development (1, 14), the entrenched linear formal approach persists. This entails a long and expensive process, from developing new varieties within research institutions to producing and distributing certified seeds of these varieties that farmers use (15, 16). Government and donor investments have predominantly favored the linear formal pathway, yet significant crop diversity originates from farmers' informal seed systems. Informal seed system actors are also key in supplying this diversity to farmers, often without support or recognition. According to 2014 seed production data for 17 major crops from the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), informal producers supplied 100% of the seed/planting materials used for bananas, cassava, Irish potatoes, pigeon peas, and sweet potatoes in Uganda. The informal producers also provided 87% to 99% of seed for beans, groundnuts, sorghum, sesame, millet, and cowpeas (1), and this proportion remains the same for dryland crops in 2024 (17). The formal seed system actors primarily focused on hybrid seeds of maize and selected vegetables.

Despite significant investments in the formal seed system, it often fails to deliver good quality planting materials for key livelihood and food security crops used by smallholder farmers, adversely affecting crop production (14). This shows the need for implementing the government's new pluralistic seed system development policy, going beyond the formal breeding, delivery, and adoption (BDA) pathway, to sustainably enhance farmers' access to quality seeds of diverse crops and varieties.

1.2 Study objectives

The overarching goal of this study is to propose pathways to enhance links between diversity holders, such as genebanks and other seed system actors, in order to facilitate sustainable access to diverse crops and varieties by farmers in Uganda. Drawing on the experiences and perspectives of multi-level seed system actors, the study identifies opportunities to enhance the performance of key seed system functions — variety development, seed production, and seed distribution.

The study has three specific objectives to achieve this goal. Firstly, it aims to characterize the Ugandan seed system by mapping and assessing the roles, activities, and performances of seed system actors across the key seed system functions. We identify the strengths and weaknesses in the existing system(s) and describe the current dynamics of seed governance in Uganda.

Secondly, the study aims to explore and characterize farmers' seed systems in four selected study sites by mapping the diversity of major crops, examining the sources of seeds utilized by farmers, and identifying seed security challenges. Cultural, political, climatic, market, and other factors influencing farmers' preferences and needs are essential in this exploration.

Based on the two first objectives, the third objective is to develop pathways to strengthen linkages between seed system functions at both national and local levels. The proposed pathways were validated through discussions with seed system actors in a Kampala roundtable workshop in April 2024. Subsequently, the pathways will inform the design of pilot projects aimed at enhancing the coordination among actors and improving the efficiency of the seed system.

The report is structured as follows. Chapter two presents the approach and methodology, describing the conceptual framework, methods, and the case study sites. Chapter three presents the study's findings, encompassing stakeholders' assessment of seed system functions at the national level and seed system outcomes or seed security as experienced by farmers and other actors at the local level. In chapter four, we discuss three proposals to improve linkages in the seed system, focusing on practical strategies for connecting diversity holders with downstream actors in the long term. In chapter five, we summarize the study's main findings and provide key insights on improving the coordination between seed system actors in Uganda at both national and local levels. We have also outlined specific recommendations for short-term interventions that can be implemented to achieve better results.

2 APPROACH AND METHODOLOGY

2.1 Conceptual framework

To enhance farmers' access to crop diversity by connecting diversity developers and maintainers with downstream seed system actors, understanding farmers' seed systems in each region is crucial (18). A seed system includes all actors, activities, and institutions (both formal and informal rules and customs) involved in conservation, variety development, seed production, and seed distribution (19). In recent years, scholars have outlined the key functions of a seed system (20-23). Figure 1 illustrates the perspective on the connections between actors, seed system functions, and seed security outcomes that underpin this study.

The "onion" in the center of Figure 1 illustrates the nested nature of seed system functions. Firstly, actors in all seed systems develop and maintain genetic resources and varieties, with several of them involved at different levels. In the formal seed system, which includes developing and registering new varieties and producing and marketing certified seeds through registered outlets, variety development, and management are distinct activities managed by different actors. In contrast, within an "informal" seed system, where farmers undertake seed selection, production, storage, and dissemination, variety development and management is an integrated function.

Secondly, all seed systems must ensure the production of seeds from available varieties. Seed production methods include on-farm seed production by farmers, centrally planned production by companies, or locally coordinated efforts facilitated by entities such as seed producer cooperatives, out-grower farmers, individual and group farmers, and community seed banks. The quality of seeds these actors produce varies depending on their technical skills, storage infrastructure, financial capacity, and economic objectives.

Thirdly, seeds must reach farmers for crop production. Seeds are distributed through both market and non-market mechanisms. On-farm seeds may be reused, exchanged, sold, or shared, while centrally

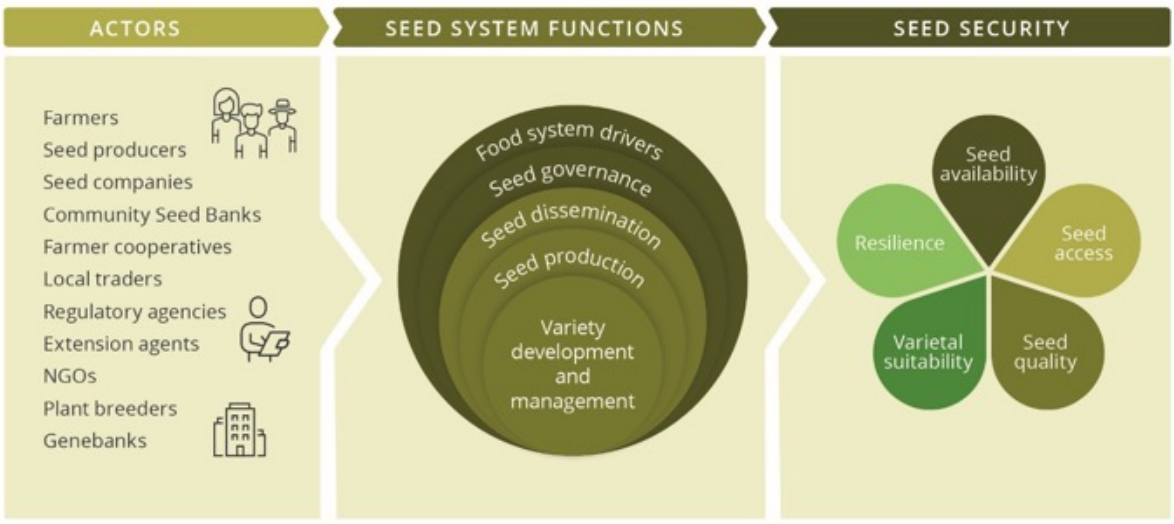


Figure 1. The conceptual framework for analyzing seed system actors' contributions to seed system functions and their seed security outcomes for farmers.

produced seeds are distributed through sales outlets. Community-based institutions often employ seed loan systems or directly sell seeds to users.

In this report, we use these three core seed system functions to analyze the roles of different actors in the Ugandan seed system. Additionally, we contextualize these functions with analyses of seed governance regimes, including governance of landraces (24)[1], farmers' varieties (25)[2], new plant varieties/cultivars, seed production and marketing, and broader food system drivers, such as the political economy of seeds in Uganda.

As illustrated on the right-hand side of Figure 1, the performance of seed system functions can be assessed in terms of seed security outcomes for farmers. Variety developers and custodians must produce varieties with desirable agronomic and quality traits. Seed producers play a crucial role in ensuring an adequate supply of high-quality seeds. Actors involved in seed dissemination should establish reliable mechanisms for farmers to access seeds.

2.2 Data collection and analysis

In this study, we predominantly utilize qualitative data to characterize seed systems. The qualitative data was collected through key informant interviews (KIIs) with seed system actors at local and national levels and focus group discussions (FGDs) involving male and female farmers. Additionally, we used participant observation in seed system meetings and conducted document analysis of various published and unpublished reports, statistics, and policy documents.

At the outset of the BOLD project, in October 2022, we organized a one-day inception workshop for national seed system actors. The workshop, attended by 41 representatives from various sectors, addressed issues related to the linkages between crop diversity holders (genebanks and breeding programs) and downstream seed system actors—the workshop aimed to enhance coordination and collaboration to enhance performances among seed system actors in Uganda. During the workshop, the following points were addressed: presenting and discussing the seed systems that Ugandan farmers use, identifying challenges related to institutional and policy practices, understanding the role of genebanks in Uganda and international germplasm exchange, analyzing the contribution of each seed system actor to and dependence on all other actors through cross-linkage exercise, and generating empirical information on policy and practices for improved performances of the Ugandan seed system. The diverse participants represented genebanks, breeding programs, variety release and seed certification authorities, extension services, private and public seed companies, farmer organizations, non-governmental organizations (NGOs), and academia.

In addition to generating qualitative information on the linkages and coordination between diversity holders and downstream seed system actors, the insights gained from the inception workshops supported and guided the identification of key actors in the Ugandan seed systems. FGDs with farmers at the study sites further identified local seed system actors. On this basis, KIIs were conducted with 73 participants (49 men and 24 women), involving representatives of 34 national actors and 39 local actors (Table 1) purposively selected due to their involvement in seed system functions and governance.

At the national level, these actors comprised representatives from genebanks, national plant breeding programs within agricultural research institutions, seed companies, regulatory authorities overseeing variety registration, release, seed quality

1 No fixed, internationally recognized taxonomic or legal definition of landraces exists. Recently, researchers defined a landrace as "a crop variety or crop population managed by farmers through cultivation, selection, and diffusion, which is typically adapted to a local area and traditional farming systems, has a recognizable identity and geographic origin, and is often genetically heterogeneous (Khoury et al., 2021). However, it is essential to note that the term landrace remains controversial as some actors see the coining of the term as discrediting farmers' roles in crop evolution.

2 Similar to farmers' varieties, no internationally recognized taxonomic or legal definition of landraces exists. However, plant genetic resource practitioners understand farmers' varieties as crop varieties developed and managed by farmers, especially crop varieties developed through farmer-led participatory plant breeding and participatory variety selection (Halewood 2016).

Table 1. Key Informants from study sites and at the national level.

	Hoima	Soroti	Sheema	Kabaale	National	Total
Male	8	3	6	7	25	49
Female	3	6	5	1	9	24
Total	11	9	11	8	34	73

control and certification, agricultural extension agents, NGOs operating across regions, agriculture and seed policy advisors at the Ministry of Agriculture, and scholars specializing in seed systems and plant breeding at Makerere University and Consultative Group for International Agricultural Research (CGIAR). At the local level, actors encompassed farmers' cooperatives, including local seed business (LSB) groups and district farmers' associations, community seed bank (CSB) groups, agrodealers, seed companies, NGOs collaborating with farmers, and seed/grain traders, along with agro-processors contributing to the seed systems used in the study sites.

To assess the performance of the Ugandan seed system with seed system actors, we used a set of structured questionnaires called the Seed System Toolkit (26). This toolkit was developed by the Norwegian University of Life Sciences's (NMBU) Seed System Lab in collaboration with partners in Bhutan, Ecuador, Tanzania, and Uganda. The Seed System Toolkit integrated various existing tools and methods developed by scholars and institutions (27-33). In Uganda, this toolkit, which is comprised of questionnaires for FGDs and KIIs, underwent pretesting in Entebbe's Wakiso district. A group of 25 farmers, including 17 women and eight men, participated, leading to questionnaire adjustments and finalization. The research team then submitted the final toolkit and sought ethical approval from the Institutional Review Board (IRB) of the Alliance between Bioversity International and CIAT. After obtaining approval, the team initiated the data collection planning process. The NMBU research team's participation was guided by the research ethics guidelines of NMBU (34) and Norway's standards for research ethics in social sciences, humanities, law, and theology (35). Based on these protocols, NMBU researchers submitted a notification form to the Norwegian Centre for Research Data (NSD), which was approved before fieldwork.

In our investigation of seed system functioning, KII participants were probed about actors' interests, roles, and activities within each seed system function — variety development and management, seed production, and seed dissemination. This included discussions on strengths and weaknesses and how governance related to genetic resources, variety development/release/marketing, seed quality control/certification and marketing, coordination among actors, and other contextual factors influenced the seed system functions. Participants also shared their perspectives on seed system development.

Our understanding of the seed system at the local level or seed systems farmers use in Ugandan mainly relies on 16 FGDs with farmers and concurrently conducted local KIIs in the study sites. FGDs were carried out in Hoima, Soroti, Sheema, and Kabaale districts from April to June 2023 (Figure 2). These districts were selected to include variations in essential aspects of smallholder farming in Uganda, such as agroecology, cropping systems, farm landholding, infrastructure facilities, and degree of commercial orientation. The 16 FGDs comprised eight sessions with male farmers, each assessing their two key crops per site, and eight sessions with female farmers, each assessing their two key crops per site (Table 2). The FGDs at the study sites enabled an understanding of crop diversity, trends in diversity changes, challenges in crop production, current and historical seed sources utilized by farmers, seed availability, quality, and accessibility from various sources.

FGD participants were chosen in collaboration with local leaders, research assistants, extension workers, and local NGOs with the deliberate intent of incorporating various age groups, genders, social statuses, and levels of participation in community activities. To ensure inclusive engagement and to capture gender-specific roles and activities in crop and variety choices, seed selection, production, maintenance, distribution,

Table 2. Participation in Focus Group Discussions in the four study sites.

	Hoima	Soroti	Sheema	Kabaale	Total
Men	10	7	7	7	30
Women	11	7	8	9	35
Total	20	14	15	15	65

and use, separate FGDs were conducted for male and female farmers.

The qualitative data, obtained through KIIs and FGDs, was documented on flipcharts, recorded using audio devices, and transcribed into Word files. These files were then uploaded onto MAXQDA software for analysis, and farmers and seed system actors' practices and experiences were summarized from the transcripts. The summaries were systematized in Excel and categorized by seed system functions, enabling comparisons across actors and functions to extract insights for seed system development in Uganda. Secondary data from diverse sources were employed to triangulate the primary data collected to ensure robustness. In December 2023, the research team participated in an international convening[3] on evidence and actions concerning policy and practice in seed sector development in Uganda. This event served as a platform to validate emerging insights from ongoing KIIs, FGDs, and document analysis for the study.

Description of Study Sites

This research was conducted in four districts in Uganda—Hoima, Soroti, Sheema, and Kabaale—depicted in Figure 2 and described in Table 3. It encompassed seed system actors with national relevance based on their mandates, roles, and activities.

Hoima, situated in Western Uganda, displays diverse agroecology. Its highland areas are conducive to agroforestry farming systems, where farmers integrate trees and shrub species into their mixed crop-livestock farming practices. Crop-livestock mixed farming is the cultivation of crops and the raising of cattle, sheep, goats, and equines by the same economic entity, such as a household or a "concession," with animal inputs (e.g., manure, draft power) being used in crop production and crop inputs (e.g., residues, fodder) being used in livestock production (36). The mid-hill region holds a substantial landmass dedicated to coffee and tea farms, playing a pivotal role in local and national economies. The dryland smallholder crop-livestock farming extends to agropastoral/pastoral corridors along Lake Albert, covering approximately 35% of Uganda's land surface. This corridor, diagonally stretching from southwestern to northeastern Uganda, exhibits semi-arid agroecological characteristics, including low and unreliable rainfall and prolonged drought, dominated by pastoral rangelands (Table 3). Food insecurity, particularly during March and April—following the extended dry season and preceding the onset of the rainy season—is widespread in numerous households in Hoima (37). Hoima enjoys moderate infrastructure and market accessibility, supported by well-connected roads and extension services. Additionally, the district benefits from the products and services provided by the Bulindi Zonal Agricultural Research Institute (BuZARDI), community seed banks (CSBs), farmer cooperatives, local agricultural extension agents, local seed businesses (LSBs), agrodealers, private seed companies, and grain traders. Collectively, these actors facilitate access to agricultural technologies, including new, improved varieties and high-quality seeds.

Soroti district, located in the northeastern Savannah drylands agroecological zone of Eastern Uganda, features mixed crop-livestock systems with a dominance of annual crops. The lower elevation and semi-arid climate are conducive to hardy, dryland crops. Still, the region faces challenges such as unreliable rainfall, leading to floods, droughts, and soil degradation

3 A gathering convened by CGIAR's Seed Equal Initiative on "Policy and Practice in Seed Sector Development in Uganda: An International Convening on Evidence and Action," held from December 11th to 13th, 2023, in Entebbe, Uganda.

compared to the Kabaale and Hoima districts in Uganda's southwestern and western highlands (38). Cropping practices are primarily monocropping, occasionally incorporating intercropping, strip cropping, and crop rotation to enhance soil quality. Farmers also adapt by planting different crop species during bimodal rainfall's first and second seasons. Over the past three decades, Soroti has witnessed a shift from traditional farming, marked by changes in crops and varieties, increased monocropping in commercial crops, a rise in food crop marketing, and cultivation in swamps/wetlands (39). Limited access to land pressures farmers, mainly men, to seek off-farm income-generating opportunities. Regarding infrastructure needs, Soroti faces challenges with poor rural road connections. Despite this, the district enjoys a relative benefit from access to agricultural technologies, quality seeds, and extension services provided by key seed system actors such as the National Semi-Arid Resources Research Institute (NaSARRI), agrodealers, seed companies, a CSB, farmer cooperatives, local agricultural extension agents, NGOs, and agro-processing plants such as fruit factories.

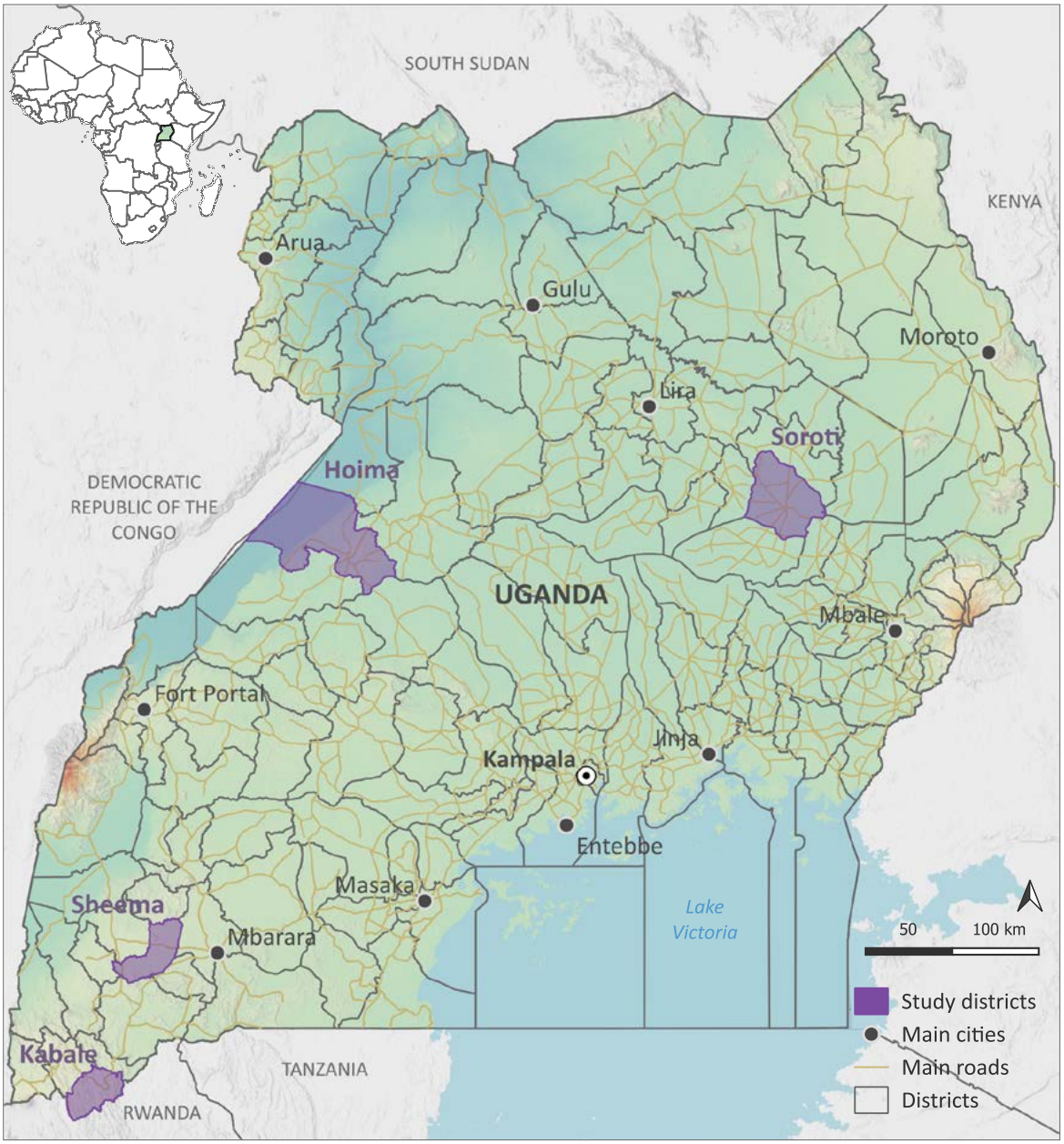


Figure 2. Map of study sites in Uganda

Sheema is located in Uganda's Southwestern high- and rangeland agroecological zone, which features a diverse landscape of rolling hills, mountains, valleys, and flat areas with sandy, clay, and slightly laterite loam soils suitable for crop cultivation. The local economy thrives on cash crops and cattle production. Agriculture, particularly livestock-based income (25%) and crop production (69%), plays a pivotal role in the district's economy and employment. Challenges include unpredictable rainfall, increased diseases and pests, and significant youth out-migration, leading to a shortage of labor (40). Key local government interventions focus on "matooke" (banana), coffee, beans, and groundnut production, emphasizing input supply and training through extension services. Regarding seed system development infrastructure, Sheema has a moderate infrastructure with poor road connections that can be difficult to access during the rainy season. Its proximity to the Mbarara Zonal Agricultural Research and Development Institute (MbaZARDI) means that extension services, quality seeds, and new technology are accessible. Access to services is facilitated by key seed system actors such as agrodealers, seed companies, a CSB, farmer cooperatives, local agricultural extension agents, NGOs, and agro-processing plants, including maize and animal feed processors.

Kabaale is situated in the highland range agroecological zone of Southwestern Uganda, close to the Rwandan border. It features interconnected cultivated high hills and steep valleys. The district is experiencing land degradation due to extensive deforestation, overgrazing, and intensive cultivation, which includes wetland valleys and steep hillslopes. An intensive terrace-based agricultural system has been developed to address these challenges, incorporating government-led soil and water conservation measures. Kabaale is an area with a high rural population density, and its challenging topography has led to changes in cropping systems. Many farmers have shifted towards monocropping highly productive cash crops like the Irish potato, leading to a decline in traditional crop rotation, fallowing, and intercropping of cereal and legume crops. The region's climate is unreliable and fluctuates rapidly, commonly described as "summer every day and winter every night," with increasingly cooler and wetter conditions with increasing elevations. The district benefits from robust road infrastructure, serving both Rwandan and Ugandan markets, and excellent extension services provided by the Kachwecano Zonal Agricultural Research Institute (KaZARDI). Various seed system actors, including agrodealers, seed companies, CSBs, farmer multi-purpose cooperatives, local agricultural extension agents, and NGOs, actively promote sustainable agricultural production systems focusing on soil and water conservation and crop diversification.

Table 3. Key characteristics of study districts

Characteristics	Study districts			
	Hoima	**Soroti**	**Sheema**	**Kabaale**
2023 Estimated total population	390,000	597,000	208,500	337,800
Ethnolinguistic group	Bantu-Banyoro	Nilotic-Ateso	Bantu-Banyankole	Bantu-Bakiga
Average land holdings (ha)	5.4	2.3	4	2
Agroecology	Lake Albert Crescent — characterized by a steep rainfall gradient from highland agroforestry, mid-hill coffee and tea, small-scale mixed farming, and commercial to dryland small-scale agriculture and agropastoralism	Eastern Semi-arid Savannah, flat with undulating hills - poor, shallow, and light-textured soils with high sandy loam content	Southwestern wet and drylands, with sandy clay loam soils with low to medium productivity	Southwestern highlands, mountainous, high hills, and deep valleys with mostly volcanic-rich soils
Farming systems	Crop-Livestock mixed farming	Crop-Livestock mixed farming	Crop-Livestock mixed farming	Mainly crop cultivation
Major crops	Maize, Beans-Cassava, Groundnut, Banana, Sweet Potatoes, and Rice	Cassava, Sweet Potato, Groundnut, Sorghum, Maize, and Cowpea	Banana, Beans, Coffee, Millet, Sweet Potato, Cassava, and Maize	Beans, Sorghum-Irish Potato, Cabbage, Maize, Millet, and banana
Altitudinal ranges in meters above sea level (masl)	800-1100	900-1340	1400 – 1800	1200-3960
Annual temperature ranges (^{0}C)	18-30	18-30	17-30	13-23
Annual rainfall ranges (mm)/Yr.	800-1500	800-1200	1000-1300	1000-1500
Rainfall pattern	Bimodal	Bimodal	Bimodal	Bimodal
Access to irrigation	No	No	No	No
Farmers' commercial orientation	Low	Medium	High	Medium

Sources: Okonya et al. (38), Juraez and Tusiime (41), Haneishi et al. (42), and Wortmann and Eledu (43)

3 RESULTS

3.1 Crop varietal dynamics and challenges in Ugandan agriculture

In this study, we assessed seed system outcomes across four study sites (Figure 2) and identified gaps and challenges based on information from farmer FGDs. They provided insights into their experiences related to food and livelihood security, covering aspects such as crop diversity they use, varietal suitability of these crops for their market, agronomic and culinary needs, availability of sufficient quality seeds from various sources, and the accessibility of supply from these sources in terms of cost and proximity.

3.1.1 Crop diversity

Our assessment shows that the intricate interplay of diverse human cultural, social, economic, and environmental factors—encompassing geography, soil, bimodal rainfall, and climate stresses—has resulted in substantial genetic, varietal, and species diversity in food and cash crops in Uganda, aligning with various previous studies on crop diversity in the country (44-47). In the four studied districts (Figure 2), each representing distinct agroecological conditions (Table 3), farmers enumerated a diverse array of cereal, legume, root, tuber, banana, vegetable, fruit, spice, oil, and industrial crop species. Despite the reduction and disappearance of certain cultivated crop varieties, substantial genetic diversity is still evident in all the study districts, as illustrated below. Existing crop diversity shows that Ugandan food systems have a robust foundation of crop diversity.

According to FGD participants in Hoima, agricultural practices vary across the district's agroecological zones. The highlands support thriving agroforestry species such as mango, pawpaw, jackfruit, guavas, avocado, and vegetables, while coffee and tea farms dominate the mid-hill area. Cereal, legume, and oil crop species cover the dryland areas of the district. In Hoima district, major food crops cultivated, as reported by FGD participants, include beans, maize, cassava, sweet potatoes, millet, groundnuts, bananas, rice, and millet. When asked to prioritize their two most important crops, male farmers identified maize and beans. Female farmers, while aligning with male farmers on the first choice of beans, selected cassava as their second most important crop (Table 4). Notably, beans exhibit the highest intraspecific diversity from varieties listed by FGD participants. The male farmer group listed seven maize and 18 bean improved and local varieties. The women farmer group listed 16 beans (with some overlapping with varieties listed by men) and eight cassava local and improved varieties currently cultivated in their communities. Moreover, male FGD participants identified two maize varieties and three bean varieties that were abandoned locally. In comparison, female FGD participants listed five varieties of cassava and four varieties of beans that they said were abandoned in recent years in their community due to a combination of agronomic, market, and culinary characteristics (Annex 1). Further discussion on varietal suitability is provided below in section 3.4.2.4.

According to FGD participants in ***Hoima***, agricultural practices vary across the district's agroecological zones. The highlands support thriving agroforestry species such as mango, pawpaw, jackfruit, guavas, avocado, and vegetables, while coffee and tea farms dominate the mid-hill area. Cereal, legume, and oil crop species cover the dryland areas of the district. In Hoima district, major food crops cultivated, as reported by FGD participants, include beans, maize, cassava, sweet potatoes, millet, groundnuts, bananas, rice, and millet. When asked to prioritize their two most important crops, male farmers identified maize and beans. Female farmers, while aligning with male farmers on the first choice of beans, selected cassava as their second most important crop (Table 4). Notably, beans exhibit the highest intraspecific diversity from varieties listed by FGD participants. The male farmer group listed seven maize and 18 bean improved and local varieties. The women farmer group listed 16

Table 4. The first and second key crop preferences among FGD participants interviewed in study sites emphasize gender dynamics. Blue and orange highlighted numbers represent male and female FGD participants' first (1) or second (2) crop choices.

Crop	Hoima		Soroti		Sheema		Kabaale	
	Men	Women	Men	Women	Men	Women	Men	Women
Beans	2	1			2	2	1	1
Maize	1							
Banana					1	1		
Cassava		2	1	2				
Sweet potato			2					
Groundnut				1				
Sorghum							2	
Irish potatoes								2

beans (with some overlapping with varieties listed by men) and eight cassava local and improved varieties currently cultivated in their communities. Moreover, male FGD participants identified two maize varieties and three bean varieties that were abandoned locally. In comparison, female FGD participants listed five varieties of cassava and four varieties of beans that they said were abandoned in recent years in their community due to a combination of agronomic, market, and culinary characteristics (Annex 1). Further discussion on varietal suitability is provided below in section 3.4.2.4.

In the ***Soroti*** district, farmers primarily cultivate hardy dryland crops adapted to moisture stress, as reported by FGD participants. These include sorghum, millet, groundnuts, cowpea, mung bean (green gram), and linseeds (simsim). Common crops like beans, cassava, sweet potatoes, and maize are grown in higher elevations, along with horticultural crops such as oranges, mangoes, pineapples, avocadoes, and citrus. FGD participants also mentioned the recent introduction of sunflower and soybean to the Soroti agricultural landscape. Male farmers identified cassava and sweet potato as the two key crops grown in their community and listed 3 and 8 currently cultivated varieties, respectively. Female farmers prioritized groundnut and cassava. They listed a very high intraspecific diversity of groundnut (15 varieties) and seven cassava varieties their community grew. Despite this, male FGD participants reported that seven cassava varieties and five sweet potato varieties had not been encountered in their locality in the past few years. Female FGD participants did not notice two cassava and three groundnut varieties they knew existed in their communities (Annex 1). See further discussion on the causes of these local losses in the varietal suitability section of the seed security situation of the key crops below.

Sheema district supports the most crop diversity of all the districts we assessed. According to FGD participants, major crops grown in the diverse agroecological landscape for food and livelihood security include bananas, beans, coffee, millet, sorghum, sweet potatoes, Irish potatoes, cassava, vegetables, maize, groundnuts, soybeans, and fruit trees like passionfruit, papaya, and mangoes. Both male and female farmer groups identified bananas and beans when asked to identify their two key crops for food and livelihood security in Sheema (Table 4). Remarkably, female farmers listed 24 banana and 41 bean varieties by name, while male farmer groups listed 25 banana and 21 bean varieties. Many varieties identified by male and female farmer groups shared names, while numerous others had different names for both crops. Like Hoima and Soroti, FGD participants in Sheema listed varieties that used to be commonly

grown but are no longer cultivated in their community. The male group reported four banana varieties, while the female group reported five varieties of bananas and beans, each of which farmers have not grown in recent years (Annex 1).

Kabaale's extraordinary agricultural landscape — terraced high hillsides, deep valleys, and diverse agroclimatic conditions, including semi-arid climatic conditions- supports a diverse range of crops listed by FGD participants. These include Irish potatoes, sweet potatoes, beans, sorghum, green leafy vegetables, eggplant, cabbage, bananas, coffee, tea, millet, yam, fruit trees, wheat, cassava, peas, cowpeas, and pumpkins. In Kabaale, male FGD participants prioritized beans and sorghum as their top two crops. They identified 17 bean varieties and four sorghum varieties currently cultivated. They also identified six bean varieties that used to be grown but are no longer planted by farmers. Female FGD participants chose the Irish Potato as their key crop and listed eight currently cultivated varieties. The female FGD groups said two potato varieties they knew are no longer found in their community. Their second key crop, beans, has 19 cultivated varieties, but many bean varieties (16 varieties) have been out of cultivation in their locality over the last few decades (Annex 1).

We asked the FGD participants to rank the most vital crops for food and livelihood security in all four districts. We analyzed the male and female FGDs' crop mentions as most important, the top two key crops they selected, and their rating of the crops's importance for food and livelihood security (1-10) to determine crop ranking. Accordingly, the FGD participants in the study sites recognized 20 crop species, including the eight key crops — beans, maize, banana, cassava, sweet potato, groundnuts, sorghum, and Irish potato as essential for food and livelihood security. Among all study sites, beans have the highest diversity, followed by bananas and groundnuts. For the ranked list of importance, refer to Table 5.

Beans are a crucial legume staple in Uganda. They provide a significant source of protein and play a vital role in improving soil fertility for farmers through crop rotation, intercropping, and mulching with chaff. In addition to being a household food item, beans are one of Uganda's major agricultural exports, ranking third in the region after Kenya and South Sudan. Maize is an important cereal crop grown for household food consumption and income generation. Uganda also exports maize to the Democratic Republic of Congo (DRC) and Kenya.

Bananas are ranked high by farmers. In Sheema and Kabaale districts, both men and women widely grow bananas. According to the 2019 agricultural census survey, over 47% of farmers cultivate bananas in Uganda, with the Western Region leading at over 80%, followed by the Central Region (10%), the Eastern Region (8%), and the Northern Region with less than 1%. FGD participants reported that bananas are a staple food crop and income source in their communities. This perennial, all-season crop ensures year-round availability, contributing to long-term household food security. Bananas offer multiple uses beyond cooking and consumption without requiring advanced skills for cultivation. Dried banana leaves are used as roofing materials, stalks are valuable cattle feed, the leaves and stems of some varieties have medicinal properties, and the bark is woven into traditional baskets. According to Mulugo et al. (48), the myriad uses, cultural practices, and beliefs linked to the cultivation of banana landraces have discouraged farmers from adopting tissue-culture bananas advocated for combatting Banana Xanthomonas wilt in Uganda. This reluctance stems from the technology's disregard for cultural significance, taste preferences, diverse uses, and farmers' skills and knowledge necessary for planting and maintaining the new tissue culture cultivars.

Additionally, banana leaves are used for cooking and steaming food, while specific banana varieties are used in crafting local alcohol brews such as 'waragi' and banana juice. Banana is frequently intercropped with coffee, maximizing crop production and productivity on diminishing arable land for smallholder farmers. According to van Asten et al. (49), this intercropping practice enhances coffee quality, promotes biodiversity, and contributes to soil and water conservation.

According to FGD participants, cassava and sweet potatoes are essential tubers and root crops for household food security and income in most places in Uganda. Cassava is an adaptable crop, and starch

is a vital ingredient for making local brews; the leaves are a valuable vegetable, the juice from its bitter root is used to heal a running stomach, and the stalks are used as firewood. Similarly, sweet potatoes have diverse applications: the tubers are chopped, dried, and stored as the family food reserved for future use, the vines are utilized as animal feed, and the leaves are consumed as vegetables. According to FGD participants, groundnuts are highly valued because of their importance as a source of food and income and their high market demand and price.

Sorghum and millets are important staple crops for income, food, and nutrition security. They are used for household food consumption and the production of local alcohol. Sorghum stems are used

Table 5. Diversity of the most crucial crops cultivated across the study sites in Uganda. The frequency of crop significance was determined by mentions from FGDs (out of 16 FGDs from the four districts, i.e., one male and one female FGD per site), listing them as the most important crops. It also considers the number of FGDs that designated the crops as their two key crops for food and livelihood security, including designation overlaps between men and women groups and the group rating of crop importance on a scale from 1 to 10 by FGDs. The color-based grouping is a loose guide for crop categories grown at varying scales. Blue indicates primary staples widely grown for household food consumption, while Yellow denotes supplementary crops grown for specific use, e.g., stews for cultural uses. Green indicates crops grown for income and as supplementary crops.

Crops	The frequency of the crop significance being mentioned by the FGDs	Number of FGDs designating the crop as their key crop	Number of FGDs ranking crops in decreasing order of importance on a scale from 1 - 10									
			1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Beans	8	6	3	3				1		1		
Sweet potato	8	1		1		1	3	1	1	1		
Maize	7	1	1		1	1	2	1	1			
Finger millet	7				1	2		1	1	1		1
Banana	6	2	2				1	1	2			
Cassava	6	3	1	2				3				
Groundnut	6	1	1		1	2				1	1	
Sorghum	5	1		1	2				1	1	1	
Cabbage	3					2					1	
Coffee	3				1		1					1
Cowpea	2				1				1			
Eggplant	2								1	1		
Green gram	2										1	1
Green leafy vegetables	2										1	1
Irish potato	2	1		1	1							
Rice	2						1			1		
Sesame	2										1	1
Pigeon pea	1										1	
Pumpkin	1									1		
Soyabean	1											1

for mulching, fencing, and thatching houses. Millet is less susceptible to pests in storage, has a longer shelf life, and is culturally significant for the Banyankole, the Bantu ethnic group in Uganda. Furthermore, millet is considered a medicinal crop for diabetic patients owing to its high iron content.

The FGD narratives underscore farmers' priorities in crop selection. Key factors include household food security, emphasizing crops that contribute to long-term stability because of their perennial or long-term storage characteristics. Income generation has a significant influence, and farmers particularly value crops with high market demand and crops that offer diverse uses. Priority is given to resilience options in crops such as cassava and bananas, as they exhibit agronomic elasticity to climate change impacts. Additionally, intercropping practices are taken into consideration. As we will discuss in section 3.2 about the roles and activities of actors in variety development and management, these considerations are vital in farmer-driven dynamic and experimental management of crop diversity. In addition to farmers' roles in creating and managing massive crop diversity, the species and varietal diversity mentioned by FGD participants also result from reintroducing lost and rare yet valuable varieties by genebanks and improved varieties from formal plant breeding programs. For instance, significant numbers of maize, cassava, groundnut, bean, and sweet potato varieties farmers grow are improved by formal breeding programs. The different actors' contributions suggest that plural and integrated seed systems involving diverse actors are central to creating and managing crop diversity for resilient smallholder agricultural production (Annex 2).

3.1.2 Drivers of change in crop diversity

During our FGD sessions, we asked the participants about changes in crop cultivation in their communities over the past decade. Our questions covered crop introductions, abandonments, and shifts in cultivation. Notable changes were mainly observed at the variety level, involving adopting newly introduced varieties and abandoning older ones, especially landraces and farmers' varieties. Participants also noted the introduction of new crops like fruit trees and vegetables to their cropping systems. They reported fluctuations in the number of farmers and the area allocated to different crop species and varieties, indicating both declines and increases.

The participants in the FGD concluded that the key crops they identified in their districts (Table 4) have shown an increase in cultivated area and the number of farmers growing them across all selected sites. In addition to the key crops selected by FGD groups, coffee cultivation has expanded in most study areas in Uganda. However, sorghum in Kabaale declined despite its significance for food security. Various new varieties of existing crops in the country, e.g., apple, cabbage, and watermelon in Hoima, sunflower, soybean, and orange in Soroti, and apple and vanilla in Sheema, were introduced over the past decades, as reported by farmer groups.

The increased cultivation of the key crops is primarily attributed to their importance for household food consumption and higher market prices. Farmer groups also credit this increase to improved access to seeds/ planting materials, facilitated by government and development partner support. The assistance includes input provision and training on better agronomic techniques for introduced varieties, aiming to improve resistance to pests and diseases and enhance overall yields in food security and commercial crops. Introducing the new fruit trees and vegetables in Uganda aligns with government policies that promote a "competitive, profitable, and sustainable commercial agriculture sector" (1), expecting to boost exports and income for producers and agro-processors involved in cultivating these newly introduced commercial crops.

Farmers adopted new crops due to subsidized prices, fast maturity, marketability, income generation, and perceived medicinal value (e.g., orange for COVID-19). For instance, the Sheema local government's website has reported the distribution of various inputs to farmers through the government subsidy program, Operation Wealth Creation (OWC), since 2014. These inputs include 1,137,882 coffee seedlings, 10 tons of improved bean seed, 10 tons of improved maize seed, 8,049 mango seedlings, and 3,890,000 tea seedlings.

The FGDs with farmers revealed a decrease in farmers' cultivation of certain crops and the abandonment of various varieties in their locality. Declining crops include rice and yams in Hoima, soybeans, cowpeas,

and sorghum in Sheema, as well as millet and wheat in Kabaale, according to FGD participants. Furthermore, 'old' varieties with poor agronomic and culinary traits have declined, notably for beans and cassava, mainly replaced by better-yielding improved varieties. Farmers in Soroti reported a shift in crop preferences, favoring new, improved varieties of maize and beans and the initiation of seasonal swamp cultivation of rice, sugarcane, and vegetables. In recent years, crops like maize and groundnuts have been mainly cultivated as mono-crops in Soroti. According to FGD participants, this transformation is generally attributed to the introduction of novel varieties of crops like beans and bananas alongside emerging market opportunities. Changing farmer preferences, driven by external factors like market dynamics, climate change impacts, and the absence of improved seeds/planting materials tailored to farmers' needs, contribute to the decline of traditionally popular crops.

Farmers have stopped growing many crop varieties that take longer to mature in favor of faster-maturing varieties. Other internal factors, such as labor shortages, poor soil fertility, limited access to irrigation, and shrinking land sizes, have also contributed to the decline of less-performing varieties, e.g., poor yield under these conditions. These factors have forced farmers to focus on less labor-intensive, high-yielding, and highly marketable crops like bananas and beans. Policies and programs also affect crop preferences. For example, the expansion of boarding schools and children's feeding programs in Kabaale has led to increased demand and price for vegetables and beans included in the program, compared to crops like millet, which have declined. Moreover, government input subsidy programs, such as the OWC and extension services, provide training on good agronomic practices and information dissemination related to adapted varieties and good quality seeds, focusing on commercial crops. These programs do not support minor traditional crops, as reported by FGD participants.

3.1.3 Main agricultural problems perceived by farmers and trends in producing key crops.

As part of our investigation into the factors influencing agricultural production in Uganda, we conducted FGDs with participants to identify the primary challenges faced by their communities and determine which farmers or households are most affected by these challenges. Despite variations in agroecological zones and household socio-economic conditions across the study sites, we found that common challenges affecting smallholder crop production include agricultural land degradation, climate change, and plant pests and diseases.

The participants in the FGD explained various challenges associated with agricultural land degradation that have been impacting crop production. These challenges include continuously fragmented and diminishing land size and declining soil fertility due to intense cultivation, worsened by topsoil removal intensified through flooding. Furthermore, inadequate soil moisture that fails to support plant growth during dry spells and heightened soil acidity, informally referred to as "soil poisoning" by farmers, affects crop production. In addition, farmers linked a range of climate change-related weather extremes to their crop production challenges. These include unpredictable or delayed rains and early cessation during planting seasons, extended dry spells, insufficient rainfall, hailstorms, strong winds, heavy rains and flooding, and high temperatures, often characterized by farmers as excessive sunshine.

Farmers reported increased plant diseases and pests, which they attribute to climate change. The changing biotic and environmental factors have led to significant obstacles in crop production, according to participants in the FGDs. For example, bean farmers, who make up most farmers, face challenges from drought, heavy rains, and armyworm infestations. Most bean varieties do not thrive under such conditions. In Uganda, traditional animal pests such as monkeys, rodents, and birds also challenge farmers. However, specific plant diseases and pests have a noticeable increase. Participants in the discussion noted an increasing prevalence of bacterial blight and fungal diseases, which are believed to be caused by changes in temperature and precipitation. These changes mainly affect RTB crops. Farmers also identified an increase in pests and diseases, including cereal stem and cob borers, legume pod borers, aphids, and other sucker bugs. These pests affect crops like potatoes, legumes, and vegetables. Furthermore, termites, banana

weevils, and bean flies were mentioned as particularly harmful to cassava, bananas, and beans.

Moreover, the heavy reliance on rainfed farming and limited access to irrigation impacts productivity and the variety of crops cultivated by farmers, ultimately affecting crop diversity. According to Uganda's recent national irrigation policy document (50), the irrigated area accounts for less than 0.5% of the total potential irrigable area, and approximately 1% of agricultural households in the country practice irrigation. Poor performance of the seed system also poses additional challenges for crop production, as FGD groups identified issues such as the scarcity of quality seeds, limited access to seeds due to distance and transportation costs to urban selling points, high seed costs, and dishonest sellers offering counterfeit seeds. Though difficult to quantify, these factors significantly impede agricultural productivity. Factors like labor shortages, inadequate infrastructure (such as poor roads and storage facilities), market-related problems (including lack of markets for agricultural produce and fluctuating prices), insufficient capital for input purchase, and inadequate extension services were highlighted as overarching challenges affecting agriculture production among smallholder farmers in the study areas. Farmers specifically expressed concerns about the lack of quality extension services related to new diversity. They emphasized the need for training to enhance knowledge and skills for adopting new varieties to help them tackle the challenges in their crop production.

While the challenges mentioned above affect all farmers, specific groups, particularly poorer households and women, emerge as the most vulnerable to factors impacting crop production, including those linked to farmland degradation, climate change, and plant pests and diseases. Limited capital poses a significant obstacle for poor farmers, hindering their access to essential inputs like certified seeds, chemical fertilizers, and pesticides. Women, specifically, confront additional hurdles due to restricted landholding sizes, especially in flood-prone areas, leading to erosion and degradation of their lands. This vulnerability underscores the need for targeted interventions to support these marginalized groups in enhancing their resilience to agricultural challenges.

During our research, we discussed the crop production trends of selected key crops across study sites for the past three growing seasons with focus group participants. The focus groups collectively concluded that while the production of key crops remained generally unaffected, seasons were categorized as good, average, or bad in terms of production due to variable weather conditions, prevalent pests, and diseases, inadequate and untimely input supply, or a combination of these factors. The participants also expressed a need for improved crop varieties that are tolerant to moisture stress, especially in beans and lodging-tolerant and bacterial disease-resistant banana varieties, as well as timely access to high-quality planting material.

3.1.4 Challenges in seed production of the key crops

Farmers have identified several agricultural challenges that affect the production of seeds and planting materials. These challenges include limited access to production factors like land and inputs. Local initiatives, such as those undertaken by farmers, community-based actors, CSB groups, and LSBs, need more support than well-funded and technically well-staffed private sector schemes and government programs.

Beans are a key crop for food and livelihood security in three of the four study sites and are widely cultivated throughout the country. However, group seed producers need more access to high-quality early-generation seeds (EGS). The six farmer groups that identified beans as their key crop mentioned seed quality issues are also related to a lack of knowledge about optimal seed moisture content and proper drying before storage. Moreover, beans are susceptible to pests and diseases, such as the bean weevil and fungus, which affects their storability.

In RTB crops, including cassava, Irish potato, sweet potato, and banana, bacterial and fungal plant diseases affecting both field and post-harvest stages are the predominant challenges known to farmers. Conversely, farmers perceived minimal issues with seed production for key cereal crops such as sorghum and maize. These crops have good storability and are less susceptible to pests for short-term or seasonal storage.

Overall, farmers and key informants agree that more skills and capacity are needed in post-harvest handling, adequate storage practices, poor storage facilities, and challenges related to diseases and pests. Limited support for community-based quality seed production exacerbates these issues.

3.2 Functioning of the seed system: a bird's-eye perspective

3.2.1 Variety development and management

In this report, variety development and management as a core seed system function covers roles and activities such as conservation, breeding, and maintenance of varietal diversity. In Uganda, the key actors engaged in plant variety development and management include farmers, genebanks, plant breeding programs, CSBs, NGOs, and agricultural extension agents, each contributing with diverse focuses and capacities (Annex 2).

Individual farmers in Uganda adeptly manage their crop diversity by cultivating diverse crop species or different improved varieties and landraces of the same species, rotating crops seasonally, intercropping or allocating small areas for multiple crop species, and cultivating commercial varieties separately. Genetic resources scholars describe this as farmer-driven *dynamic on-farm management* of crop diversity (51). Farmers manage varietal diversity to meet varied needs for food, income, livestock feed, fencing, thatching for houses, soil fertility improvement, climatic considerations, nutrition, and culinary and cultural preferences. In groups like CSBs, farmers also engage in *experimental dynamic management of crop diversity* (52). In Uganda, this involves reintroducing both lost and rare crop species and varieties from genebanks and other communities, selecting and enhancing varieties of different crop species through farmer field schools, participatory plant breeding, and variety selection (PPB/VS) to adapt crops to their growing conditions and market needs. Farmers' varieties emerging from farmers' experimental dynamic management practices, such as PPB/PVS, are promoted by farmer groups and development organizations as varieties with superior genotypes and hold potential for wider marketing (53, 54). While the activities of farmers have contributed to the vast crop diversity present in Uganda today, market, agronomic, and changing culinary demands have also led to a decline of a considerable number of varieties in farmers' fields. CSB groups and NGOs working with them indicated that limited access to improved varieties tailored to climate-related stresses, poor soil fertility, and rising pest and disease challenges, compounded by constraints encountered by farmers' groups like CSBs in terms of land, labor, and resources, has resulted in declining varieties, specially landraces.

The national *genebanks*, specifically the National Plant Genetic Resource Center (NPGRC), and other conservation facilities such as Mbarara Zonal Agricultural Research and Development Institute (MBAZARDI) regional *in-situ* banana germplasm collection center, Makerere University Regional Centre for Crop Improvement (MaRCCI), and the Alliance Bioversity International and CIAT bean core collection at the National Agricultural Research Organization in Kawanda, Botanic Gardens in Toro Kingdom, and Tea Germplasm collection in Kyenjojo district play a crucial role in both in-situ and ex-situ conservation and providing facilitated access to germplasm for farmers, breeders, and other researchers in Uganda.

Beyond its mandate to collect and conserve plant germplasm for all crop species, the National Genebank or NPGRC is tasked with coordination of in-situ and ex-situ complementarities for conservation and also enhancing germplasm utilization through characterization, evaluation, and genetic enhancement in Uganda. To maintain indigenous crop species and varieties, NPGRC works closely with communities to develop their capacities. NPGRC is mandated to enhance community-based and on-farm conservation of crop diversity through collaboration with CSBs and similar farmer groups. Since its establishment in 2004, the NPGRC has collected and conserved 4184 accessions from 30 crops, representing 68 crop species out of the country's total of 96 crop species, according to an assessment conducted in 2023 (55)The evaluation reveals that the genebank has not collected representative samples for all crop species across the country's diverse agroecological zones. As a result, the nation's crop diversity is not fully protected from

potential losses and is not secured for future uses.

The NPGRC has significant deficiencies in technical capacity, infrastructure facilities, equipment, and established processes, which pose serious security risks for its conserved ex-situ collections (55)). These shortcomings do not meet the standards outlined in the genebank operating procedures for acquisition, seed handling, conservation, regeneration/multiplication, safety duplication, and documentation processes (56). However, the NPGRC's active engagement with communities and individual farmers through CSBs, demonstrations, participatory plant breeding, germplasm evaluation initiatives, diversity fairs, and direct introduction of various landraces to farmers' fields presents an opportunity. These efforts have strengthened the conservation of landraces on-farm through collections and safety duplication from CSBs, and they enhance crop diversity by creating linkages with the seed systems used by farmers in Uganda.

In the past decade, Uganda's policy and strategic directions have guided the reorientation of scientific *plant breeding and variety development* towards a pluralistic approach, embracing public, private, and people partnerships. Since the establishment of the National Agricultural Organization (NARO) in 1992 and before the shift, the national strategy for variety development was primarily led by public plant breeding programs concentrating on major cereal crops such as maize to enhance "calorie security." The private sector was primarily involved in the seed production and distribution functions, with a few exceptions, such as NALWEYO SEED Company (NASECO), which also conducted plant breeding. Since 2005, under the National Agricultural Research Act, NARO has been an umbrella for all National Agricultural Research Systems (57), specifically on plant breeding through a network of agricultural institutes working on specific crops in different agroecological zones of Uganda. This network of decentralized institutions comprises seven National Agricultural Research Institutes (NARIs) and nine Zonal Agricultural Research and Development Institutes (ZARDIs) (36). These institutes are crucial in providing agricultural research services in relevant agro-ecological settings and producing basic seeds used by LSBs and seed companies for the production of certified and QDS. Under the new strategy, Uganda's breeding programs focus on major cereals, neglected and underutilized crop species, and indigenous crops to address market, environmental, and nutritional security needs (14). Arguably, the historical focus on some crops over others is reflected in the types and number of available improved crop varieties in Uganda listed in the NARO annual "variety allocation list," which was notified to seed producers. For instance, the notification on October 15, 2023, included 21 maize varieties and 11 rice varieties, compared to five sorghum varieties, three sesame varieties, and one millet variety (58). The allocation list is the list of varieties whose early-generation seeds (EGS) are available for uptake by seed companies for multiplication. It is determined through demand forecasting of varieties selected from the national variety catalogue.

NARO has focused on developing modern varieties for commercial production, maintaining developed varieties, and producing breeder seeds. It also provides EGS, specifically pre-basic and basic seeds, and collaborates with the private sector and farmer groups in joint variety development, dissemination, and technology commercialization. Furthermore, NARO has collaborated with international agricultural research organizations such as the CGIAR centers. According to key informants, this collaboration has played a catalytic role in national breeding efforts, enabling NARO to access a broader genetic pool for plant breeding and enhancing its capacity-building efforts (Annex 2). Dominantly, NARO's plant breeding approach has been conventional. In a few cases, some varieties have been developed, at least partially, through Participatory Plant Breeding or Participatory Variety Selection (PPB/VS) approaches (59-64). According to plant breeders interviewed, the limited use of participatory methods in the plant breeding and evaluation of new varieties, particularly for RTBs, indigenous vegetables, and minor cereal species, is due to financial constraints, insufficient human resources (especially the absence of breeders in many crops), and challenges in implementing plant breeders' rights, as elaborated below in the discussion on the governance of Intellectual Property Rights on new improved plant varieties.

Across the different activities related to variety development and management—such as variety conservation, enhancement, breeding, variety selection, and maintenance —development organizations, including NGOs and government extension agents, provide support to key stakeholders such as farmers, CSBs, genebanks, and national and zonal plant breeding institutions in Uganda. The Embassy of the Kingdom of the Netherlands, the Department for International Development (now the Foreign, Commonwealth & Development Office) of the United Kingdom, the World Bank, the Bill & Melinda Gates Foundation, the United States Agency for International Development, Food and Agriculture Organization of the United Nations, CGIAR centers, NGOs such as the Alliance for a Green Revolution in Africa, Oxfam Novib, Integrated Seed Sector Development, PELUM Uganda, Farm Africa, and HarvestPlus are among the key partners offering financial and technical support, which includes training in plant variety selection and good agronomic practices for quality seed production to key actors involved in plant variety development and management activities.

According to key informants, despite capacity development efforts like crop-based and community-based interventions, the government's limited budget and unpredictable funding and technical support from some development organizations hamper the sustainability of commitment and participation in plant variety development. This suggests the necessity for multi-stakeholder approaches to establish sustainable crop variety development and management models, integrating financial support and designated roles for key stakeholders to coordinate activities across themes and actors. Informants told us that the messages from some actors involved in agricultural extension, especially NGOs providing training, often diverge from conventional approaches, as explained by two participants during the roundtable meeting to validate this research report in Kampala in April 2024 as follows:

> "NGOs advocating for crop diversity conservation sometimes wrongly label NARO-varieties developed through a project funded by donors like the Bill & Melinda Gates Foundation as GMOs. This misinformation is challenging for farmers to verify as NARO does not communicate well about its technologies, and farmers do not trust NARO's varieties. Some politicians also publicly repeat these allegations, which further misleads farmers despite the misinformation. However, NGOs and politicians overlook that donor support does not influence NARO's breeding agenda. Conversely, NARO lacks a strategy to simplify variety descriptions for farmers, which hinders their understanding of new varieties and their characteristics. Educating farmers on distributed technologies and enhancing seed packaging with clear labels are crucial for better dissemination and informed decision-making."

NGO promotion of indigenous crops and varieties also often carries negative messages, discouraging farmers from adopting improved varieties. On the other hand, government extension agents concentrate solely on promoting improved varieties through field demonstrations and training and ignoring other valuable varieties managed by farmers. The divergent approaches by NGOs and government extension create confusion among farmers, who receive conflicting information from these sources. This lack of extension service harmonization among actors further highlights the need for coordinated agricultural extension services to provide accurate information about existing varieties—landraces, farmers' varieties, new cultivars, and old improved varieties[4]—enabling farmers to make informed choices based on their growing conditions.

4 ***Old improved varieties*** in this report refer to improved varieties that the formal seed system has released in the past. They are not currently on the list of varieties whose early-generation seeds are available (except when regulatory authorities fail to update the list despite the unavailability of their EGS) for certified and quality-declared seed (QDS) producers. However, they are integrated into the farmers' seed system, i.e., maintained and used by farmers. In some seed system literature, these are called obsolete varieties. However, critics say these varieties are obsolete/abandoned/removed from the variety list for certified and QDS production for the formal seed system actors but remain very important for farmers or not obsolete varieties for farmers.

3.2.1.1 Governance of landraces, farmers' varieties, and new cultivars/plant varieties

In this governance section, we categorize crop diversity into two main types to explore the formal and informal rules relevant to their management. These include landraces and farmers' varieties, managed by farmers through cultivation, selection, and diffusion and adapted to local areas and traditional farming systems. Farmers create varieties through experimentation with genetic materials, introducing new diversity through various selection practices, and hybridizing local and improved varieties. Thus, farmer varieties are often heterogeneous and maintained by farmers due to specific and unique traits that are either functional, agronomic, or both. These also function as genetic resources available for breeders. Governance also involves new cultivars or improved plant varieties bred by scientists that are genetically homogeneous and display high yield potential under suitable growing conditions.

Governance of PGRFA access and benefit sharing

Farmers and local communities enjoy free access to all plant genetic resources under the 2005 "National Environment (Access to Genetic Resources and Benefit-Sharing) Regulations" (8). Other users engaging in research, bioprospecting, conservation, industrial application, or commercial use of plant genetic resources, derivative products, and intangible components (e.g., local knowledge and information) can access them by applying for an access permit issued under these regulations by the designated competent authority—the National Council for Science and Technology, in consultation with relevant lead agencies like NPGRC. While this study does not investigate the perception and experiences of international users with access to Ugandan genetic resources, our key informants in Uganda generally reported that all users have had facilitated access upon obtaining an access permit and signing material transfer agreements with the competent authority. According to distribution data from NPGRC, the center provided 929 accessions of different crop species, including crop wild relatives, to various users between 2019 and 2023. During this period, NARO was the recipient of the highest number of accessions (414), followed by CIAT (306), farmers (116), and Soroti University, who received 86 accessions. It's worth noting that NPGRC has limited capacity for collection and characterization despite this considerable distribution.

Uganda has recently established institutional coordination measures for Access and Benefit-Sharing (ABS) through a Memorandum of Understanding signed in 2015. The signatories include the Uganda National Council for Science and Technology (UNCST), the National Agricultural Research Organization (NARO) through the Plant Genetic Resources Centre (NPGRC), and the National Environment Management Authority (NEMA). This framework delineates the responsibilities and functions of each institution in the interim period. UNCST, acting as the competent national authority, manages all requests for genetic resources, processes access applications, coordinates access providers' activities, and facilitates necessary agreements. Requests of material included in the International Treaty for Plant Genetic Resources for Food and Agriculture (ITPGRFA) fall under the scope of the NPGRC. NEMA handles all other genetic resources, including materials conserved in situ by communities and any other PGRFA not included in the multilateral system's list of 64 species of ITPGRFA Annex I crops. As per this framework, UNCST retains its role as the competent authority for ITPGRFA's Standard Material Transfer Agreements (SMTAs) and MTAs under the Nagoya protocol (65).

Governance of farmers' variety exchange and registration/ intellectual property rights

Farmers' informal seed exchange networks function based on trust, local customs, and norms and are crucial in governing landraces, farmers' varieties, and new cultivars. In addition to individual households, understanding the exchange of experiences and knowledge among farmer seed networks forms the foundation for decisions on whether to retain or discard varieties based on culinary and cultural needs, pest and disease resistance, yield potential, and suitability for cultural preferences and livestock feed. Over the past few decades, CSB groups in Uganda have organized with the support of non-governmental development organizations and Alliance Bioversity International and CIAT to promote the exchange of knowledge and seeds. This effort has led to the selection of locally adapted and preferred crop varieties. As reported

by FGD participants and key informants from farmer organizations like CSBs, participatory farmer variety selection has yielded locally adapted bean varieties and other preferred crops, contributing to crop diversification aligned with local agro-ecological and cultural conditions. Although the national seed policy recognizes and promotes pluralistic seed system development involving stakeholders like CSB groups (1), realizing targets set by the national seed strategy for registering farmers' varieties by 2020 (14) remains unfulfilled. The Seed and Plant Regulations of 2017, developed to guide the implementation of the Seed and Plant Act of 2007 (national seed law), lack provisions for registering farmer-selected/developed varieties. Despite advocacy by NGOs and farmer organizations, the absence of legal and technical support impedes the registration and marketing of farmers' varieties, hindering seed production and farmer innovation, as outlined in the Plant (Quality Declared Seed) Regulations of 2020 (4). However, a recent update we learned when writing this report indicates that a guideline for registering farmers' varieties is currently submitted to the Cabinet of Uganda for consideration.

Concerning ownership, Uganda's national seed policy recommends "the development of a new law to safeguard and preserve indigenous knowledge related to local varieties while effectively protecting community intellectual property rights" (1). NGOs, development organizations, and farmer groups advocate for such a law, especially concerning registering farmer-developed/selected varieties and granting community intellectual property rights. Proponents argue that this can enable benefit-sharing (monetary and non-monetary) for farmers from genetic resources with potential commercial value, enhancing the collective capacity of groups like CSBs. The registration of farmers' varieties is also aimed at improving access to quality seeds of a diversity of crops not formally produced through the formal breeding processes, such as traditional leafy vegetables and some neglected and under-utilized species. The push for farmers' variety registration is because seeds can only be officially produced and marketed from the list of registered varieties on the national catalogue.

In a national seed policy workshop[5] organized by CGIAR in Entebbe in December 2023, and a subsequent roundtable meeting we organized in Kampala in April 2024 to validate this research report; significant opposition to farmers' variety registration emerged from key stakeholders in the formal seed system. This opposition was notably voiced by breeders, intellectual property experts, and policy researchers. In Uganda, the absence of clear taxonomic and legal definitions, proper identification, and naming protocols for landraces and farmers' varieties presents significant hurdles in registering these varieties, a goal promoted by various development partners and farmer groups. For instance, farmers frequently name newly developed varieties after old improved varieties that are no longer listed in the national catalogue, owing to shared traits such as seed size and color, as observed by bean breeders. Moreover, trial materials, including breeders' lines, often remain in farmers' fields after on-farm evaluations, complicating variety identification. These materials are gradually perceived as landraces and can eventually end up in NGO-supported participatory variety selection trials of landraces, some of which can emerge as farmers' varieties with superior genotypes, according to breeders. Inconsistent naming practices, limited extension, and information on new cultivars or improved varieties exacerbate the challenge.

Additionally, the absence of clear timelines for transitioning new cultivars from certified seed production in formal systems to old improved varieties managed in farmers' seed systems complicates variety management in Uganda. These issues underscore the urgent need for precise definitions, naming protocols, and improved communication within Uganda's seed system actors, including farmers. Concerns also emerged regarding who is responsible for registering farmers' varieties, given that multiple farming communities in various locations may manage a single variety. Ownership and access concerns that could impede the free flow and exchange of varieties among farmers and breeders have also been highlighted.

5 A gathering convened by CGIAR's Seed Equal Initiative on "Policy and Practice in Seed Sector Development in Uganda: An International Convening on Evidence and Action," held from December 11th to 13th, 2023, in Entebbe, Uganda.

Despite recognition in the national seed policy (1), breeders, regulatory authorities, and technocrats from the MAAIF still express concerns that proposed farmers' variety registration and community property rights may hinder the free flow of genetic resources among farmers and researchers in the country.

Governance of improved variety registration and release

In the formal breeding programs, notable successes have been achieved in developing high-yielding crop varieties, mainly maize and beans. However, according to informants from private seed companies, challenges arise in registering and releasing new plant varieties. A prominent issue is the lack of independent Distinctness, Uniformity, Stability (DUS) tests and National Performance Trials (NPT). Due to resource constraints preventing the establishment of the proposed semi-autonomous and independent authority under the 2018 national seed policy (1), Uganda Plant Health and Inspectorate Agency (UPHIA), the government has tasked the National Agricultural Research Organization (NARO) with overseeing plant variety registration and release. The NARO conducts these tests on behalf of and with oversight from the National Seed Certification Service (NSCS). Informants expressed concern about the conflict of interest in such a setup where NARO, through its commercial wing NARO Holding, is also interested in marketing its varieties, currently licensing to private seed companies and fetching license fees. Furthermore, there is discontent among private seed companies regarding the high fees charged by NARO for conducting these tests, which, according to informants, exceed the prescribed amounts in the regulations (UGX 350,000 for DUS and UGX 800,000 for NPT). This issue, documented in a recent study on the regulatory framework in the Ugandan seed sector (15), is said to impede healthy competition, hindering innovation and delivery of quality new plant varieties tailored to the needs of Ugandan farmers.

Governance of Intellectual Property Rights for improved varieties

The ownership of new and improved cultivars in Uganda is regulated by the 2014 Plant Variety Protection Act (PVPA) in harmonization with the 2018 Intellectual Property Policy and the 2018 NARO Guidelines for Intellectual Property Management. However, according to many breeders interviewed, the PVPA has not yet been implemented due to the absence of regulations that guide its implementation, which, in their opinion, hinders private sector investment in the country's plant breeding industry. For farmers, the PVPA explicitly states that smallholder farmers face no restrictions in saving, exchanging, reusing, and selling protected varieties for non-commercial purposes. It is also important to mention that Uganda is not a member of the International Union for the Protection of New Varieties of Plants (UPOV).

The private sector also faces challenges in registering and marketing new varieties developed outside Uganda due to provisions in the 2007 Ugandan Plant and Seed Act and its 2016 implementing regulation, which predates the adoption of the COMESA Seed Trade Harmonization Regulations. Despite endorsing the 2014 COMESA Seed Trade Harmonization Regulations (20), the Ugandan National Variety Release Committee does not exempt varieties listed on the COMESA Variety Catalogue from the DUS test and NPT. Instead, the committee requires a one-season NPT to assess the varieties' suitability for adaptation to Uganda's agroecology before permitting their listing on the national variety catalogue and marketing within Uganda. In the 2023 national policy convening mentioned above and roundtable meeting for validating this report, our research team noted breeders' endorsement of the committee's position on COMESA varieties, highlighting the importance of one-season NPT to ensure adaptation of the new plant varieties to Uganda's diverse agroecology.

3.2.2 Seed production

Various actors produce and store different types of seeds in Uganda (Annex 2). These include farm-saved seeds of landraces, farmers' varieties, and older improved varieties managed in the farmers' seed systems, early generation seeds (EGS)—breeders' seeds, pre-basic and basic seeds of new cultivars, and certified and quality-declared seeds (QDS) of registered improved varieties.

Seed production in farmers' seed systems

Depending on the crops, farmers in Uganda produce, use, and exchange 70–100% of seeds, encompassing a

diverse range of varieties (1, 14, 66-70). They employ local knowledge and adhere to local farm-saved seed production practices, including selecting healthy and large-sized cobs, panicles, or seeds before or after harvest and sorting by variety or color. Storage practices involve sun-drying, hanging over a kitchen fire for smoking, keeping underground (e.g., seed potato) for a limited period, covering with dry grass (seed potato), utilizing dry containers coated with ashes, mixing with insecticidal plant leaves (e.g., pepper and tobacco leaves) at storage, and farmers using tins, calabashes, bottles or airtight storage bags (71, 72). According to farmers and other informants, the heavy dependence on farm-saved seeds in Uganda is primarily due to 1) the proximity of sources for planting materials, making seeds easily accessible, 2) the lower cost of seeds, which increases accessibility, and 3) the trust in the source that farmers know well. However, concerns arise regarding the quality of these seeds/planting materials, particularly for Root Tuber and Banana (RTB) crops where diseases and pests could quickly spread. Farmers and key seed system actors, including quality control agencies and extension service providers, voice concerns about the low quality of farm-saved seeds. Poor seed quality is attributed to inadequate postharvest handling, inappropriate storage practices, poor storage facilities, and issues related to diseases and pests. However, there is a lack of support for household-level quality seed production, apart from sporadic advice from extension services as part of their broader agronomic guidance for crop production.

Seed production in the emerging intermediary seed system

In Uganda, NPGRC, with support from NGOs and other organizations like the Alliance of Bioversity International and CIAT, has established 23 CSBs in various agroecological areas. Additionally, more than 250 LSB groups, supported by the Embassy of the Kingdom of the Netherlands in Uganda and the Wageningen Centre for Development Innovation under the Integrated Seed Sector Development (ISSD) program in Uganda, operate in over 60 districts (73). CSBs produce acceptable to good quality seeds, which are expected to meet the minimum seed testing standards but not grown under a certification program. According to NGOs, CSB members, and development organizations, better seed quality was achieved due to training and the technical support provided by NPGRC, NGOs, and the Alliance of Bioversity and CIAT in collaboration with the seed certification services (74). The seed production volume of CSBs is limited due to resource constraints. For example, a highly functional and experienced CSB in southwestern Uganda has produced only 8.5 tons of common bean seeds since 2010. Over the past four years, three of Uganda's 23 community seed banks have produced and sold QDS of improved varieties registered on the national catalogue. Among these three CSBs, which have transitioned into local seed enterprises, one CSB in Hoima produced approximately 10 tons of common beans, 0.6 tons of finger millet, and 4000 banana suckers between 2017 and 2023, highlighting the significance of the market for increased QDS production and use. CSB members mainly use these seeds to meet the needs of their members, except when there is a seed surplus to sell to non-members. On the other hand, LSBs focus on producing QDS derived from basic or foundation seeds of improved varieties obtained from NARO/ZARDIs for the market. They have been producing quality-declared planting materials of beans, cassava, cowpea, green gram, groundnuts, millet, pasture seed, pigeon pea, potatoes, rice, sesame, soya bean, and sweet potato over the past decade (74). QDS undergo a lighter inspection than certified seed and can only be marketed within the geographical region of production unless authorized by the NSCS for broader distribution.

In a country where the public formal system traditionally dominates seed production, the recent expansion of CSBs and LSBs since 2010 has empowered community-based organizations to produce high-quality seeds, addressing challenges associated with farm-saved seeds (74). This improvement is attributed to training farmers in quality seed production and enhancing infrastructure for seed storage. Some LSBs also engage in out-grower contracts with private seed companies to multiply certified seeds, offering them further opportunities for skill training and knowledge in quality seed production. One of the challenges CSBs face is the inability to maintain and produce high-quality seeds, especially seeds with high genetic purity, due to technical and financial constraints (74).

This was highlighted by one of the key informants – a breeder who expressed skepticism regarding the quality of seeds at the CSBs:

> "I do not believe the community can manage the seed bank effectively. Seeds from CSBs require genetic purity, physical purity, disease-free, and viability. I doubt farmers can maintain seed viability over time; even specialized organizations face challenges."

Hence, these community-based seed producers face the main challenge of sustainability, as many struggle to operate when external support from NGOs and donors is discontinued. Addressing these challenges requires concerted efforts to provide CSBs with the necessary technical and financial support. However, currently, the government of Uganda has not allocated a budget or provided any subsidies for community-based seed producers to ensure the sustainability of these actors to continue to contribute to local seed security.

Formal seed production

Certified seed production in the formal sector begins with the multiplication of EGS, including breeder seed, pre-basic seed, and basic seed. Registered seed entrepreneurs can produce certified EGS under the provisions of the Seeds and Plant Act, 2006 (No. 3 of 2007). Only seeds of registered varieties listed in the national catalogue can be certified and distributed (15). However, there has been very little interest in taking this role. In collaboration with Uganda Prisons Limited, the public research institute, NARO/ZARDIs, has been producing EGS, but insufficient and sometimes of poor quality. Challenges in EGS production encompass inadequate funding and postharvest seed handling and storage infrastructure at NARO. Additionally, systematic information and tools for articulating seed demand and estimating EGS demand per crop and variety each season are lacking. The absence of irrigation for off-season seed multiplication, limited availability of EGS, and weak implementation of policies and regulations for quality control and certification also contribute to the lack of quality seeds of improved varieties in the market. In addition, the NSCS is faced with a shortage of funding and human resources to provide the necessary training for seed producers, field inspection, and certification services, contributing to the production of poor-quality EGS (74).

Representatives from some seed companies have expressed concerns about the lack of transparency in allocating/selling EGS to seed producers from NARO. They claim that priority is given to some entrepreneurs while others face challenges despite submitting their requests on time. To address these challenges and generate income for the research institutes under its umbrella, NARO, through its newly established business arm, NARO Holdings Ltd, has implemented a royalty system by licensing its varieties to private seed companies since 2021, according to an informant from NARO. Variety licensing has involved a mix of exclusive, semi-exclusive, and non-exclusive licenses. In the Ugandan context, exclusive variety licensing grants exclusive and non-transferable rights to produce and sell a given variety in a defined region. Semi-exclusive licensing grants exclusive and non-transferable rights to produce and sell a variety for a specified period in a designated region. Non-exclusive licenses are non-exclusive and non-transferable rights to produce and sell a given variety in a defined region for an extended period, with the option to grant the same to others (58). This variety licensing strategy is based on the types of crops (commercial, food security crop), variety (OPV, hybrid), and EGS (pre-basic, basic) involved. The NARO strategy is to boost the availability of quality EGS for a wide range of certified seed producers, facilitate broader distribution of new varieties to farmers, and generate income for the breeding programs.

About 32 registered seed companies in Uganda produce certified seeds, primarily focusing on hybrid maize, OPV maize, hybrid vegetables, and beans (7, 70). Many companies produce certified seeds by engaging trained and experienced individual seed-producing entrepreneurs or contracted farmer groups/cooperatives. The companies are also involved in seed import from Kenya, Zimbabwe, and South Africa to sell them directly to farmers and for broader marketing through agrodealers and other buyers. Additionally, the 250 LSBs specializing in QDS production mentioned in the section on intermediary actors above are increasing the availability of seeds of various open-pollinated crops (73).

The production of QDS has contributed to the increased availability of quality seeds for farmers in the past decade. A report on external project support for QDS production, covering 11 crops, indicates a total output of over 2000 metric tons per year (ranging from 295 to 5600 MT) between 2013 and 2019, including bean QDS production, which increased from less than 100MT in 2013 to 700MT in 2019 (74). For comparison, companies, including NARO, produced about 20,000 metric tons of certified seeds annually for the same crops during the same period (Figure 3; 70). The quantity of seeds from various crops tested at the national seed testing laboratory between the 2013/14 and 2021/22 planting seasons indicates an increase from 4.5 to approximately 30 tons (Figure 3). Although not categorized as certified and QDS, this demonstrates an uptick in seed certification from various producers since Uganda adopted a pluralistic seed system development policy and strategy, enabling diverse seed producers to participate in the seed market. During the validation of this research report at a roundtable meeting in April 2024, NSCS representatives emphasized that the proportion of formal see supply must have increased from the publication of the 2014 National Seed Strategy, which indicated that 85% of seed used in Uganda was sourced from the informal seed system (14). This shift is attributed to the increased volume of certified and Quality Declared Seeds (QDS) over the past decade. Beyond this information, we could not obtain detailed data on Uganda's annual production and supply volume of the different seed classes — EGS, uncertified, certified, and QDS. One can, however, get an impression of the relative importance of improved seed use from household surveys. An analysis of survey data from the World Bank's Living Standards Measurement Study (LSMS) from the 2019/2020 season in Uganda reveals that out of the 8% of the respondents reporting purchasing improved seed (of any crop), 43% said they bought certified seeds, 49% purchased QDS, while 7% responded "unknown" when asked what seed quality class they had purchased

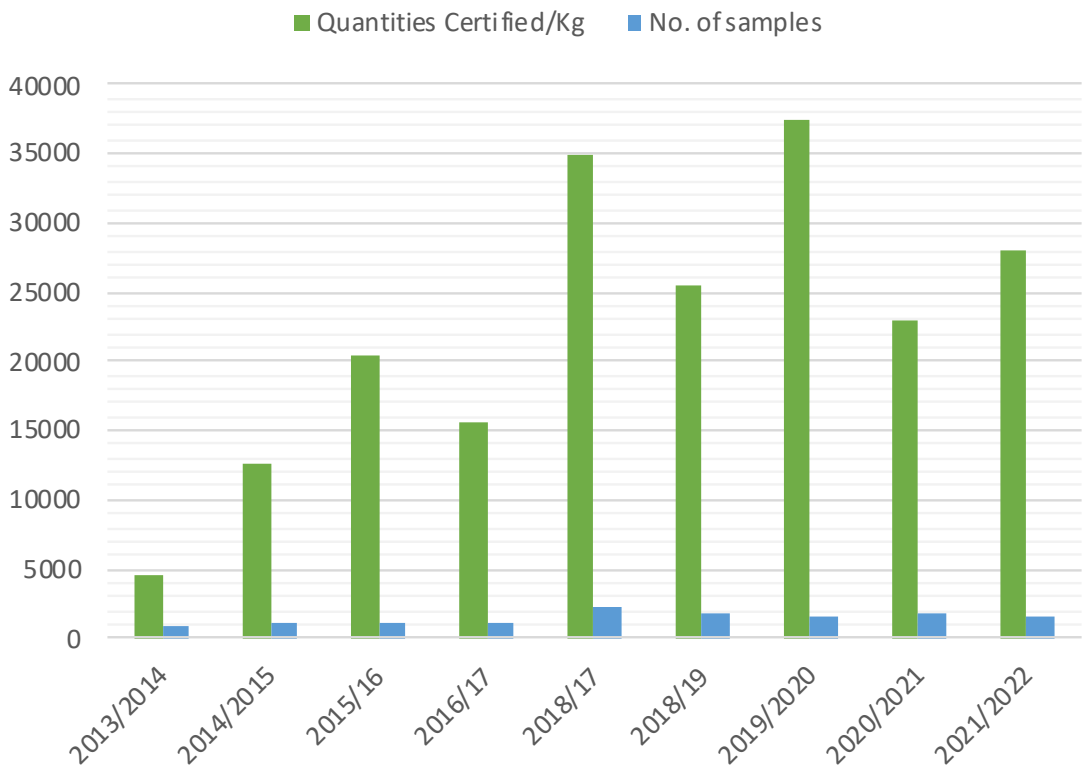


Figure 3. Quantity (in kilograms) of seeds of different crops tested at the national seed testing laboratory between 2013/14 and 2021/22 plantings seasons.

(Makate et al. forthcoming). The utilization of QDS appears comparable to that of certified seeds in Uganda.

According to key informants, the emergence of QDS production in recent years has enhanced the availability, affordability, and accessibility (due to proximity) of high-quality seeds for non-hybrid/ minor crops that the private sector often avoids due to challenges like perishability, bulkiness, and limited profitability. QDS production has also lowered the cost of seeds, making quality seeds more accessible to farmers. A recent study also revealed that the production cost of groundnut QDS by farmer cooperatives and individual seed enterprises in Uganda was a profitable seed class to produce and more affordable for smallholder farmers (75). Additionally, some informants highlighted that QDS producers provide fresher seeds than certified ones. Yet, a persistent shortage of EGS required for multiplying available improved varieties constrains certified seed production by companies and QDS production by LSBs. This shortage affects the availability of quality seeds for farmers, as reported by key informants and corroborated by earlier studies (76, 77).

Moreover, they highlighted delayed and untimely rainfall and the emergence of new pests and diseases resistant to agrochemicals, which substantially constrain certified seed production. Overall, limitations such as scarce and expensive EGS, especially for sought-after crops like groundnuts, along with factors like limited land availability and multilevel government taxation, collectively impede private sector certified seed and QDS production. On top of these are governance issues that constrained seed production, which we discuss below. In addition to the challenges mentioned above constraining EGS production, which also affects certified and QDS production by registered producers, several informants mentioned a lack of coordination among actors involved in the production of these different types of seeds, which we discuss below in connection with the governance of seeds in Uganda.

3.2.3 Seed dissemination

This section focuses on seed distribution to farmers for food production. The primary actors involved in disseminating seeds to farmers who use off-farm sources in Uganda are fellow farmers, CSB groups, individual and group local seed entrepreneurs, local traders, agrodealers, seed companies, the government's subsidy program known as OWC carried out by the National Agricultural Advisory Services (NAADS) and the military, humanitarian organizations, the Buganda kingdom, and politicians (Annex 2).

Firstly, it is important to highlight the widespread use of farm-saved seed in Uganda. This prevalence is influenced by factors such as the limited availability of certified seeds for desired crops and the high cost of certified seeds of improved varieties. Additionally, uncertainties regarding the quality of off-farm seeds and insufficient knowledge about the potential of quality seeds also contribute to the high prevalence of farm-saved seeds. According to several key informants, the widespread use of farm-saved seeds stems from farmers' familiarity with and trust in the varieties they harvest from their own crops. However, due to constraints like limited land, labor, and infrastructure, farmers cannot produce all the seeds they need and often access at least part of the seeds they plant from various off-farm sources (see Table 7 in Chapter 3.4.1). Farmers shared that they obtain uncertified off-farm seeds of diverse varieties, including landraces, farmers' and older improved varieties, which are part of the local seed system. They acquire these seeds through exchanges with relatives, neighbors, friends, or social seed networks. This exchange often occurs through gifts, in exchange for labor, or barter trade with a different crop or variety, or through cash sales. FGD participants consider their social seed networks to be the primary sources of information regarding seed origin, cost, and variety traits such as yield, taste, disease resistance, and pest resistance. Farmers in Uganda also buy uncertified seeds or grain from local markets and grain traders to use as planting material. Farmers trust their social seed networks and consider local markets more affordable when there is a thin chance of getting seeds from other sources. However, they acknowledge the risk of partial or complete crop loss that sometimes happens due to poor seed quality, mainly due to poor germination rates, especially when obtaining seeds from local markets and random traders where there is no difference between seed and grain.

The seed loan system at CSBs has emerged as an alternative channel for accessing affordable seeds locally during the past few years. The CSBs distribute seeds of local and improved varieties to their members as in-kind (seed) loans, and members return the seeds with a 50% interest in Uganda. Based on discussions with farmers and key informants, it appears that seeds from CSBs may possess a quality standard comparable to QDS. This is because the NPGRC trains the CSBs in collaboration with NSCS on seed production and conservation activities. Affordable and high-quality seed distribution by CSBs has proven beneficial for their members. However, there are still challenges to ensuring the sustainability of their seed loan system. These include problems with defaulters, delayed returns of seed loans, theft, a limited seed market, insufficient funding to pay permanent staff for technical coordination, and competition with individual farmers selling grain as seeds.

The distribution of QDS from LSBs to farmers is another rapidly expanding farmer-based initiative in Uganda. Farmers directly purchase QDS from individual seed entrepreneurs, LSB member farmers, and local LSB stores. Certified seeds are also distributed directly to farmers through cash sales at seed company wholesale and regional stores, as well as through around 3000 agro-dealers shops that distribute to seed companies. Institutional buyers, including humanitarian organizations and the government's OWC of the NAADS, purchase both certified and QDS for emergency seed distribution (78). These institutional buyers distribute seeds directly for free, at a subsidized price (especially by the OWC), or use seed vouchers, including an e-voucher system, along with fairs for seed exchange and knowledge sharing (79). Cash transfers are also made to farmers to purchase these seeds.

Farmers appreciate the diversity, affordability, and accessibility of QDS compared to certified seeds. In general, they report satisfaction with the quality of QDS. However, concerns were raised by formal seed system actors, especially private seed companies and organizations supporting formalization policy for effective private sector engagement, during a seed sector policy meeting[6] that our research team attended in Entebbe, Uganda. The main worry revolves around market distortions due to extensive and unsustainable support for QDS producers by development organizations. While the substantial support (but unpredictable) for QDS is a concern for its long-term sustainability and potential displacement of private commercial actors in the seed business, another fear reported by the private sector is the unpredictable purchase and distribution of certified seeds by humanitarian organizations, churches, politicians, traditional leaders, and the government's OWC of the NAADS, executed by the military and bypassing agrodealers. According to key informants and a recent study (70), the unpredictable purchase by government programs, among other factors, led to the issue of counterfeit seeds by agrodealers and traders. Some distributors resort to buying grain and packaging it as seeds for marketing, competing with authentic seeds, especially to fill the gaps when the certified seed is unavailable due to substantial purchases made by government programs (16). That said, during a recent workshop[7] on implementing national seed policy and regulations, discussions underscored how seed handling practices during transportation and storage lead to seed viability loss. Seeds stored for extended periods by seed companies and agrodealers under unfavorable conditions, coupled with the absence of government quality control at sales points, often result in expiration and loss of viability, despite being a legal requirement. These factors also contribute to what farmers commonly call "fake seeds" due to the lack of implementation of seed regulation. This suggests that not all seeds with poor quality, such as germination, are intentionally packed to sell as "fake seeds."

Private companies also complain about multilevel and high government taxes, scarcity of foreign currency for seed import, and limited demand for certified seeds, attributed to farmers' heavy reliance on farm-

6 A gathering convened by CGIAR's Seed Equal Initiative on "Policy and Practice in Seed Sector Development in Uganda: An International Convening on Evidence and Action," held from December 11th to 13th, 2023, in Entebbe, Uganda.

7 A gathering convened by CGIAR's Seed Equal Initiative on "Policy and Practice in Seed Sector Development in Uganda: An International Convening on Evidence and Action," held from December 11th to 13th, 2023, in Entebbe, Uganda.

saved seeds. This adversely affects their businesses and relationships with institutional buyers and agrodealers. Since 2020, a market-based input subsidy program named the Agricultural Cluster Development Project has been introduced with World Bank support to address this market distortion. Under this scheme, farmers co-fund input costs, including certified seeds, until the subsidy gradually phases out, transitioning to complete payment by farmers. However, the impact of this approach remains uncertain (70, 78). Private seed companies often cite market distortions, while farmers express dissatisfaction with the private sector's variety portfolio, limited certified seed supply, delayed seed transportation, poor seed quality, high prices, and inadequate extension services. Nonetheless, farmers appreciate agrodealers' provision of information on the plant variety they sell.

3.2.3.1 Planting material/seed governance

Formal rules and regulations alongside informal social norms, customary laws, principles, practices, and beliefs govern seed production and distribution in Uganda. This section relies primarily on a recent in-depth study assessing the implementation of the Ugandan Seed Sector Regulation by Kuhlmann et al., 2023 (15), in addition to information gathered from key informants and other document analyses. Table 6 shows government policies, strategies, laws, and regulations that govern the production and distribution of different seed classes in Uganda.

Improving the governance of early generation, certified, and QDS production and distribution is recognized as a crucial issue in Uganda for providing farmers with access to improved varieties, as per key informants. The government's ambition, as outlined in the 2005 National Agricultural Research Act, 2018 National Seed Policy, 2015 National Seed Strategy, and subsequent implementation rules and regulations, is to support public and private institutions in developing new, improved crop varieties and partnering to produce pre-basic, basic seeds and certified seeds (Table 6). However, in practice, most improved varieties in Uganda have remained on the shelf and have not been made accessible to farmers due to limitations in EGS production and distribution to certified and QDS producers. Our informants, along with recent studies (15, 74, 77), emphasized that the effective implementation of seed policies and regulatory instruments faces obstacles due to inadequate government budget allocation for essential elements such as human resources, transportation facilities, equipment for early generation, certified seed production, field inspection, quality control services,

Table 6. Seed classes and the key policies and regulations governing their production and dissemination in Uganda.

Seed class	Protocol/guideline/provisions for production and dissemination	Governance instrument
Farm-saved seeds	• Recognize seed system development in the context of transforming subsistence farming to sustainable commercial agriculture and acknowledge that 85% of seeds/planting material comes from informal sources, mainly unregulated farm-saved seeds with lower quality	2013 National Agriculture Policy
	• Emphasize the need to ensure affordable, quality seeds and planting materials from multiple sources under pluralistic and integrated seed systems to transform the informal seed system's low-quality farm-saved seeds into recognized, quality-controlled seeds.	2015 National Seed Strategy 2018 National Seed Policy
	• Propose a strategic initiative to aid village and farmer groups with support from NGOs, NARO, and extension services — through providing training and improved varieties for quality seed production — gradually transition skilled and enterprising farmers in informal seed systems to the formal seed system by expanding their seed production, establishing quality and a brand name, and marketing their seed, i.e., certified or QDS	2015 National Seed Strategy

	• Permit all registered seed merchants certified by the NSCS to produce certified EGS and certified seeds of registered improved varieties for marketing based on possessing certification of registration and trade license as a seed merchant, having knowledgeable personnel (field officer), land, equipment, contracts with seed out-growers, and a recognized EGS source for multiplication.	2007 Seeds and Plant Act
Early Generation Seeds (EGS) & 1st and 2nd generation Certified Seeds (C1 and C2)	• Make sure that official seed crop inspectors conduct EGS production field inspections and ensure that production, processing, or conditioning for sale/marketing of these seeds follows quality certification and labeling standards, complying with the minimum requirements of 2 to 3 field inspections per season depending on the crop species, i.e., check land requirement, minimum isolation distances, off types, percent other cultivars permissible, disease, weeds etc. and laboratory quality test standards specified in the regulation for certified seeds of specific crop species.	2016 Seed and plant regulation
	• Regulate the registration/certificate renewal (annually) of seed merchants/dealers and facilitate the issuance of the necessary import/ export permit and phytosanitary certificates, enabling them to participate in seed importation for the domestic market and seed exportation for regional markets.	2016 Seed and plant regulation 2016 Plant Protection & Health Act
	• Marketing and distribution (directly to farmers or through institutional buyers) is by trade license holders, including seed companies and agrodealers	2007 Seeds and Plant Act 2016 Seed and plant regulation
Quality Declared Seeds (QDS)	• Officially recognize QDS as a new seed class in Uganda and allow registered or recognized (by local government) and trained market-oriented individuals, cooperatives, or groups of smallholder farmers with land, technical knowledge, and skills for seed production. • Requires confirmation from local agriculture officers verifying the capability of registered QDS producers to possess skills and facilities for post-harvest handling and storage, ensuring access to basic seeds for multiplication.	2018 National Seed Policy 2020 Seeds and Plant (Quality Declared) Seed Regulations
	• Ensure that private para-inspectors or government inspectors from the districts and the NSCS conduct field inspections for QDS production of registered improved varieties of cereals, pulses, oil crops, and RTB crops of food security importance. • Make sure that production, processing, or conditioning for sale/ marketing of these seeds follows quality certification and labeling, adhering to the minimum requirements of field inspection (at least 10% of the field inspection for diseases, off-types, noxious weeds, etc. once per season and yield potential) and laboratory quality test standards defined for QDS in the regulation.	
	• Marketing and distribution are within communities where the QDS is produced unless authorized by NSCS (e.g., in cases of emergency) for marketing outside the community.	

and the maintenance of parent lines. The existing capacities also face challenges in prioritizing crop types, varieties, and production volume for different seed classes due to the lack of a data collection and exchange system to determine demand. Furthermore, the absence of government guidelines for coordinated production and distribution programs, i.e., EGS production and distribution to certified and QDS producers from public research institutions, creates an opportunity for corruption. This is evidenced by instances where some certified and QDS producers received preferential access to highly demanded varieties compared to other producers, creating a non-transparent situation that undermines collaboration among actors, leading to competition and mistrust, as reported by some informants.

That said, during a national seed policy convening in 2023[8], our research team observed that recent initiatives have created optimism among national formal seed system actors. These include NARO's recent licensing of public varieties to seed companies (13 licenses in 2023), which shows promise in improving access to pre-basic seeds and contributing to the production of basic and certified seeds. Efforts are ongoing in training and accrediting government seed inspectors, with 21 accreditations in 2023, aiming to ease the workload on official seed inspectors (about 19) from the NSCS providing services for about 42 seed companies, NARO/ZARDIs, and LSBs. Anticipated accreditation of private seed inspectors will further contribute positively by supporting compulsory field inspection for certified seed production (15). These recent advances align with the 2018 national seed policy[9], articulating the need for a decentralized seed inspection and certification system. Furthermore, a digital seed tracking and tracing system, monitoring seed movement from pre-basic to certified and QDS production stages and through sales (tracking) while linking each seed to its source—breeder's seed lots and production fields (tracing) — serves as a crucial tool for seed law enforcement in handling complaints and preventing the marketing of counterfeit seeds. Additionally, it encourages collaboration and transparency in the service delivery system, motivating authentic seed-producing, distributing, and regulating actors to enhance the distribution of quality seeds to farmers (80).

Since 2020, following its recognition as a new seed class in the national seed policy (1) and implementation regulation (4), QDS production and distribution have been subjected to quality control and certification. However, its full institutionalization has been slow (81). The government policy and regulatory intervention aim to enhance access to QDS for food security crops. It is also a component of a long-term plan as a way to gradually transition from poor quality seeds accessed through informal to increased quality seeds through the formal seed systems. The Ugandan QDS regulation simplifies field inspection requirements to 1-2 round inspection and 10% of the seed production field, compared to the minimum 3 rounds of inspections for all fields for certified seeds. It also reduces the number of seed lots for laboratory testing per variety to one, as opposed to multiple lots for certified seeds – this reduces the cost of production for producers and seed price for farmers. For instance, acceptable standards for bean QDS include 30% field inspection (compared to all field inspections for certified seeds), a minimum germination rate of 60% (compared to 80% for certified seeds), varietal purity of 98% (compared to 99% for certified seeds), and a maximum of 20% off-type (compared to 2% for certified seeds) (74). Source seed used, i.e., basic seeds of registered improved varieties, and other laboratory tests for moisture content, germination, purity, and disease follow the exact standard requirements as certified seeds (4).

Despite the regulatory flexibility encouraging individual farmers and group entrepreneurs to participate in QDS production and marketing, the implementation

8 A gathering convened by CGIAR's Seed Equal Initiative on "Policy and Practice in Seed Sector Development in Uganda: An International Convening on Evidence and Action," held from December 11th to 13th, 2023, in Entebbe, Uganda.

9 The decentralized services such as breeding at ZARDIs to develop agroecologically adapted varieties and local seed production and supply, building on the requirements of the 1997 Local Government Act of Uganda, which decentralized extension services to district and municipal levels. All the recent policy directions are also rooted in the democratic principles of the 1995 Ugandan Constitution, which devolved and decentralized government functions at various levels, including local entities.

of the QDS regulation lags. Similar challenges, as discussed earlier, that limit the availability and access to EGS impact QDS production along the seed value chain. New entrants in seed production, like individual farms and groups/cooperatives involved in QDS production, face limitations in a technical capacity, particularly for seed production of unfamiliar or less commonly prioritized crops in the formal sector. This also limits the ability of supporting stakeholders to provide adequate assistance. Key informants revealed a lack of investment in training and accrediting district-level para-inspectors and inadequate mobility support for existing inspectors to train farmers and inspect QDS production fields — see also Kuhlmann et al., 2023 (15). Notably, QDS producers are established and supported by external actors like NGOs and other development partners, but they lack government funding. Dependence on external actors presents a notable challenge to achieving the government's seed policy and QDS regulation goals in ensuring a consistent supply of quality seeds to farmers for the targeted food security crops. Apart from a recent training of 104 private para-inspectors by the NSCS to support the inspection of QDS fields, which was scheduled to commence inspections in 2023, according to Kuhlmann et al. (15), there were not many interventions to address the challenges facing QDS producers when this research report was written. This points to the need for prompt measures to sustain the operation of existing LSBs' QDS production and marketing initiatives.

The national seed policy of Uganda recognizes seed import for domestic markets and export for regional markets and aims to contribute to meeting national seed demand and foreign earnings, respectively. To meet high seed quality standards and achieve these goals, the government has developed stringent regulations, e.g., the 2007 Seed and Plant Act, the 2016 Seed and Plant Regulation, and the 2016 Plant Protection and Health Act. These regulations offer guidelines for safeguarding plants from destructive diseases, pests, and weeds during import and export. Usually, an import/export permit from the NSCS is required, along with a phytosanitary certificate issued by a qualified and duly authorized officer from a phytosanitary service of the Ministry based on inspection at post entry quarantine station.

The inspection process occurs at designated post-entry quarantine stations for imports and involves pre-inspection or pre-clearance for exports (6, 82). Plant varieties require approval for cultivation in Uganda to facilitate the import and export of seeds. They must be listed in the National Variety Catalogue or the Common Catalogue for COMESA member states. However, as discussed in section 3.2.3.1, the challenges of variety registration remain unresolved.

In their assessment of seed sector regulation implementation, Kuhlmann et al. (15) identified several bottlenecks in seed import and export that restrict access to commercial varieties in Uganda and limit the benefits of seed export for farmers in the region. Among other challenges, they identified the lack of a national seed board or appeals body for administrative decisions concerning seed trade. Additionally, there is no ISTA-Accredited national laboratory to issue the Orange ISTA Certificate required by certain countries for exporters, no established procedure for reporting counterfeit cases to relevant authorities, and an insufficient number of inspectors for pre-inspection or pre-clearance for seed export, as well as for post-entry quarantine stations for seed import.

3.3 Coordination among seed system actors

In Uganda, seed system actors engage in variety development, seed production, and seed distribution activities, each contributing with varying capacities as outlined in Chapter 3.2 based on information from key informant interviews (see Annex 2 for details). However, these actors are poorly coordinated (83). Variety development activities mainly involve farmers, breeding programs, and CSBs. Breeding programs collaborate with genebanks, extension services, farmers, cooperatives, and variety release agencies. Farmer groups within CSBs, supported by NGOs and international organizations like Alliance Bioversity International & CIAT and PELUM Uganda, collaborate closely with the national genebank and district-level extension agents to integrate crop diversity conservation, on-farm variety selection, and local seed production. However, resource constraints and capacity issues limit these interactions, despite efforts to engage farmers in breeding work and provide training on seed quality production.

Actors engaged in organized seed production, such as CSBs and LSBs, collaborate with NGOs and district government offices to provide farmer training but have minimal interaction with regulatory agencies and no engagement with genebanks. In contrast, seed-producing companies interact directly with public breeders, quality control agencies, agrodealers, NGOs, schools, farmers' groups, and individual farmers. However, challenges in consistent service delivery, notably from extension services, affect their overall seed production and distribution endeavors.

Farmers and local traders primarily facilitate informal seed distribution, with farmer-to-farmer interaction predominant. Grain traders directly procure grains from farmers, sell grains to them, collaborate with fellow traders to maintain price alignment, stay informed about market trends, and get assistance from financial institutions. In the formal system, seed distribution heavily relies on agrodealers interacting with various stakeholders. They primarily facilitate seed sales to smallholder and commercial farmers, who encounter challenges such as complex loan terms, inadequate storage and transportation facilities, and limited extension coverage. Formal seed distributors and grain traders typically do not engage with the national genebank and breeding programs.

Variety release and seed quality control activities are managed by NSCS and overseen by the Extension Service or NAADS at the local level. These agencies engage with breeders, farmers, and seed companies. The national genebank does not currently interact with seed regulatory agencies like NSCS. NSCS faces resource constraints and difficulties in effectively partnering with seed companies, resulting in occasional failures in quality control measures.

Seed system actors' cross-linkages

In October 2022, a participatory cross-linkage exercise (Figures 4 and 5) was undertaken, followed by in-depth one-to-one key informant interviews with key seed system actor representatives to gain comprehensive insights into coordination issues (Annex 2). During the plenary session of the inception workshop for the BOLD project's Work Package on genebanks and seed systems, local partners first confirmed a predetermined list of actors involved in Uganda's formal and informal seed systems. Subsequently, participants were grouped to conduct a cross-linkage exercise to assess the extent of interaction among seed system actors. Each group analyzed the contributions of one actor in each seed system function with all others by examining their mandates, roles, and activities. Facilitators guided discussions to identify current contributions, interactions, and coordination challenges. Contributions were assessed using a subjective four-point scale: no contribution (0), minimal contribution (1), moderate contribution (2), and significant contribution (3). These ratings were assigned based on group discussions regarding how each actor contributed to the activities of other actors, considering their diverse perspectives and nuanced opinions. The results were organized in a matrix, enabling the computation of total contributions and dependencies for each actor (Figure 4), and were plotted on a quadrant chart (Figure 5).

As demonstrated in Section 3.2, farmers emerged as significant contributors to the work of other seed system actors, ranking highest during the cross-linkage exercise. Moreover, they were recognized as the most reliant on the roles and activities of different actors across all seed system functions (variety development and management, seed production, and local seed distribution) for their agricultural production, underscoring their pivotal role and the significance of their active involvement in policy and program interventions' decision-making. After farmers, breeders (primarily from the public sector) emerged as the next notable contributors, highlighting their crucial roles in technology generation. However, breeders' effectiveness relied heavily on the support and collaboration of other actors, including access to germplasm and capacity in infrastructure and skilled human resources. The emerging local seed businesses ranked high after seed companies in quality seed production and distribution while simultaneously demonstrating a significant reliance on the roles and activities of other actors, such as for accessing early-generation seeds, receiving skill training in quality seed production and processing, and securing credit facilities. Although acknowledged for its contributions to CSB groups and CGIAR, the national genebank had the lowest overall contribution. It did not contribute to LSBs, NAADS, seed companies, and agro-dealers;

	NPGRC	Breeding programs	Farmers	LSBs	CSBs	NGOs	NAADS	Seed companies	Agro-dealers	NSCS	CGAIR Centres	Total Dependence
NPGRC		2	3	1	3	1	1	1	0	1	2	15
Breeding programs	1		3	3	2	1	2	3	0	2	3	20
Farmers	1	2		3	3	2	2	2	2	1	1	19
LSBs	o	3	3		1	2	2	1	2	2	1	17
CSBs	2	3	3	2		2	2	0	2	1	1	18
NGOs	1	1	3	2	2		1	3	2	1	2	18
NAADS	0	1	2	0	0	1		2	2	1	0	9
Seed companies	0	2	3	2	0	1	2		2	1	2	15
Agrodealers	0	1	3	1	1	1	1	2		1	0	11
NSCS	2	3	2	1	1	1	1	2	1		1	15
CGAIR Centres	2	3	3	1	2	1	3	1	1	1		18
Total contribution	9	21	28	16	15	13	17	17	14	12	13	175

Figure 4. Quantity (in kilograms) of seeds of different crops tested at the national seed testing laboratory between 2013/14 and 2021/22 plantings seasons.

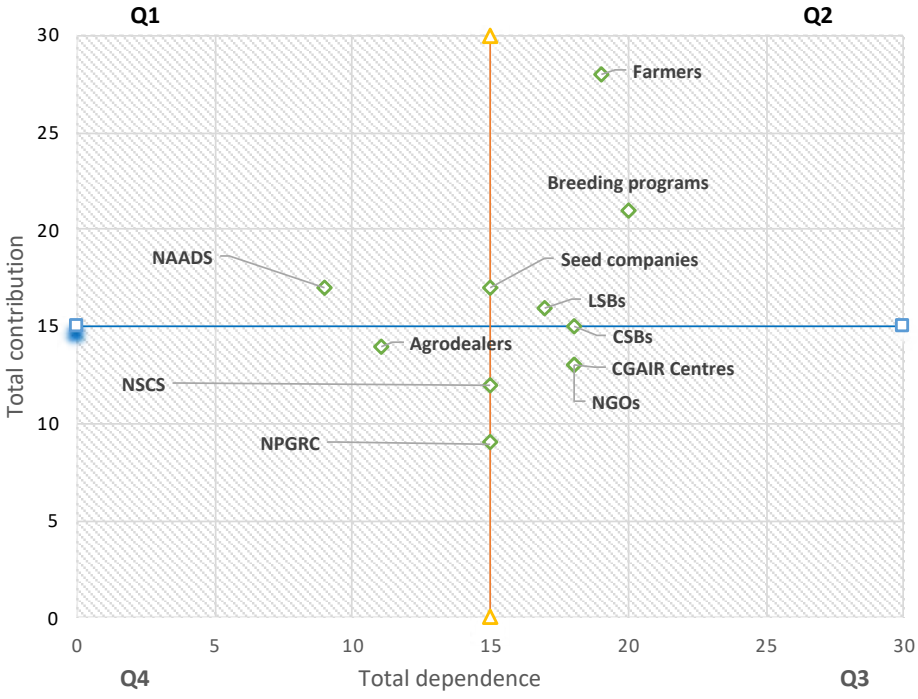


Figure 5. A quadrant chart of key seed system actors' total contributions (y-axis) and dependencies (x-axis). Actors in the upper quadrants (Q1 and Q2) contribute more to other actors, whereas those in the righthand quadrants (Q2 and Q3) depend more on others.

it only made weak contributions to farmers and breeders. This poor contribution from Genebank is primarily due to its limited linkages with key seed system actors, including breeding programs, farmers, and national extension services (NAADS). Breeders stressed the insufficient capacity of the NPGRC and the imperative to enhance its capabilities to identify users' needs and conduct extensive germplasm collection, characterization, and multiplication to utilize Uganda's genetic resources effectively. Annex 2 provides information on seed system actors' roles, activities, and capacities in Uganda. It offers insights from key informants regarding the interaction among actors and baseline information for enhancing coordination and performance.

3.4 Seed system outcomes on the ground: assessing seed security of key crops

3.4.1 Seed sources used by farmers and their relative importance.

We found that farmers access seeds from various sources, each delivering seeds of different quality standards within the formal, informal, and intermediate seed systems. Analyzing the frequency of seed sources mentioned by FGDs for selected key crops across study sites, we identified social networks, own saved seeds, and local markets as the most frequently used seed sources. In all four study sites, social seed networks emerged as the most common seed source for the key crops (Table 7), where farmers acquire seeds through labor exchange, gifts, or purchases from relatives, neighbors, and friends for the key crops. Farmer groups noted that most transactions within social seed networks involve cash, with farmers primarily purchasing planting material from acquaintances.

The second most common source of seeds mentioned by the farmers is their farm-saved planting materials. These farmers use their farm-saved planting materials or select seeds/grains from the previous season's harvest. Our qualitative analysis also confirmed that the majority of key RTB crops, such as banana, cassava, Irish potato, and sweet potato, are commonly obtained from farm-saved planting materials and social networks due to the limited availability of quality suckers and other planting materials from the formal systems (84). However, cassava cuttings and Irish potatoes are exceptions as they are distributed to some extent through formal sources such as research institutes, government subsidy programs, and aid or humanitarian organizations (Table 7). The participants of FGDs explained that farmers in their communities prefer sources they can trust to avoid the risk of disease contamination. They often rely on their farm-saved planting materials or acquire them from trusted connections in the neighborhood. As stated by a participant in the Sheema district and agreed upon by other FGD participants, "these days, we have stopped obtaining banana suckers from unfamiliar people to limit the spread of increasing banana weevil and diseases."

Farmers in Uganda also rely on local markets to purchase grains for planting from local traders. Local markets are commonly used for beans. Local seed networks and own saved seeds are familiar sources for cereals and legumes but are not widely used for groundnuts. Farmers frequently obtain groundnut seeds from local markets and formal and semi-formal seed sources (Table 7).

FGD participants in the study sites emphasized the common dissemination of seeds of new varieties from agricultural research institutes for key crops. They highlighted that farmers who evaluate and test materials from the research institutes retain seeds of new "varieties/breeding lines" from on-farm trials, which will be gradually distributed to other farmers through informal channels. While farmers generally engage positively in the participatory evaluation of breeders' material, breeders have expressed concerns about these varieties potentially being viewed as farmers' varieties. Breeders worry that some farmers might want to register and claim ownership rights over their breeding materials during the validation of this research report at the Kampala roundtable meeting in April 2024, as discussed in section 3.2.1.1 above. Furthermore, agro-dealers were the second most frequently cited formal seed source for cash crops such as beans, maize, and groundnuts. They sell certified seeds to farmers sourced from seed companies as the private sector focuses on commercial crops in Uganda (7). Apart from these sources, government subsidy and extension programs, as well as humanitarian organizations, were identified by farmer groups as

Table 7. Ranking of frequently used seed sources for the key crops in the study sites in Uganda. Yellow cells indicate that the seed sources (row) were not identified as the common ones for key RTB crops (column); Blue denotes that the seed sources (row) were not identified as the common ones for key cereal crops (column); and Green cells denote that social seed networks and farm-saved seeds were not identified as the frequently used sources for groundnuts, and seed aid and government distribution is uncommon for beans. SN (social seed network): farmers obtain off-farm seeds through labor exchange, gifts, or purchases from relatives, neighbors, and friends for different crops or varieties; Own (farm-saved): farmers use saved planting materials from the households' harvests, such as selected seeds or grains; LM (local market): farmers are buying grain as seeds from local traders; Agro-dealers: farmers purchase certified seeds from agro-dealers who source them from seed companies; Research (research institutions): farmers in varity evaluation groups retain some seeds from trial materials when they volunteer for on-farm trials and testing from breeding programs; CSBs (community seed bank): farmers obtain seed loans through their membership in or purchase from CSBs; LSBs (local seed business / cooperatives): farmers buy QDS from LSB members or LSB stores; GO (government): farmers get free certified seeds from OWC of NAADS and local politicians; Aid: farmers get free certified or QDS from humanitarian organizations.

Seed Sources	Frequency of FGDs mentioning the significance of seed sources across key crops and study sites	The number of key crops for which FGDs mentioned the seed source	Number of FGDs identifying seed sources as important for each selected key crop							
			Banana	Cassava	Sweet Potato	Irish Potato	Maize	Sorghum	Beans	Ground-nuts
SN	15	7	2	3	1	1	1	1	6	
Own	11	6	2	3	1		1	1	3	
LM	7	4			1		1		4	1
Agro-dealers	7	3					1		5	1
Research	6	4		2		1			2	1
CSBs	4	2							3	1
LSBs	3	2							2	1
GO	3	2		2						1
Aid	2	2				1				1

supportive sources of seeds for their communities. These seeds are obtained free of charge from the government OWC of the NAADS, humanitarian organizations, and sometimes from politicians, supplementing the certified seeds farmers buy from formal sources. According to FGDs, formal sources offer the least amount of planting material/seeds for RTB crops and other minor cereals like sorghum.

While generally ranked less frequently used seed sources for key crops in the study sites, LSBs and CSBs play important roles for beans and groundnuts locally. LSBs/ cooperatives are crucial sources where farmers purchase QDS from local stores or members—a trend that has increased since 2013 with support from the ISSD program funded by the Dutch Government. Additionally, humanitarian NGOs occasionally procure seeds from LSB stores, providing farmers with free QDS, thus enhancing seed accessibility and diversity, as reported by farmer groups. Farmers can also obtain seeds from CSBs, but their production and availability are limited. They can access CSB seeds through membership seed loans or purchases when surplus seeds are available after fulfilling member needs. In some study sites where Alliance Bioversity International & CIAT, PELUM Uganda, and the NPGRC have supported CSB projects, these groups have become one of the seed sources, but this is not representative across wider regions of the country.

3.4.1.1 Changes in seed sources

During our discussions with FGD participants, we asked about trends or changes in seed sources within the study sites and the reasons for the changes (if any). Our analysis of their response reveals that farmers' decisions on seed sources are complex and varied, influenced by socio-economic, agronomic, and environmental factors. Across all four sites, farmers adapt their choice of crops and varieties (hence the choice of their seed source) due to climate variations, pest and disease pressures, and changes in market preferences. For example, in the ***Kabaale*** district, access to improved varieties from research stations, particularly Irish potatoes and beans, drives a shift in seed sources. These varieties from the research stations (formal source) are favored for their higher yields and disease resistance.

Moreover, at least one CSB exists in all the study sites. Their proximity, availability of preferred varieties, and low transaction costs make them convenient options for member farmers. According to FGD participants, farmers' increasing use of CSBs is a strategic decision to ensure a more reliable local seed supply system. In ***Hoima***, for example, a CSB was established in 2018 and has since served over 500 farmers, becoming a convenient seed source, particularly for beans, a primary staple crop. Another change reported by FGD participants is the increasing tendency among farmers to move away from relying on agro-dealers due to concerns about counterfeit seeds. Instead, farmers use their farm-saved seeds and explore alternative sources like social networks in their locality.

NARO has traditionally been a significant seed provider, offering free seeds. However, there has been a decline in NARO's seed distribution frequency, with seeds entering the farming system only during participatory trials because the OWC of NAADS now runs the government seed distribution. While farmers appreciate the quality of NARO's new seeds, i.e., seeds of the trial material they retain, NARO is not a regular and reliable seed distributor. The seeds farmers get from NARO are only those they retain from the on-farm trial.

In ***Soroti***, traditional farming practices relied on their farm-saved seeds and social networks, focusing on native cassava varieties, groundnuts, and sweet potatoes. However, farmers have transitioned to more resilient varieties from the formal sector in response to climate shifts and increased pest and disease pressures. Initiatives at the National Semi-Arid Resources Research Institute (NaSARRI) and other breeding programs by the NARO have introduced groundnut, cassava, and sweet potato varieties, now produced by LSBs as QDS. LSBs, relatively new actors in the seed system, have emerged due to changes in seed regulatory frameworks allowing for QDS production. Their localized production makes seeds more accessible and affordable to farmers in Soroti. CSBs in Soroti also play a practical role, offering some farmers a diverse range of cereal and legume varieties not easily found in formal seed markets.

In ***Sheema***, banana cultivation is the most common farming practice. Farmers in this region rely on their farm-saved planting materials, as well as banana suckers acquired through their social networks. This choice is heavily influenced by proximity and trust in the sources, as there are no specialized producers for vegetatively propagated materials. Furthermore, the private sector's involvement in banana seed value chains is limited. Social networks offer diverse banana varieties that meet farmers' preferences while ensuring accessibility—meanwhile, CSBs in Sheema supply common bean seeds to their members. LSBs specialize in QDS production and marketing of bean seeds. These cooperatives distribute seeds locally and contribute to government subsidy programs like OWC.

In summary, farmers change their seed sources due to several factors, such as the search for improved yields, replacing disease and pest susceptible varieties with resistant ones, and seed availability. FGD participants noted an overall increase in local sources (diverse sources) offering quality planting material adapted to their agroecology, reducing the need for long-distance travel or transportation costs. However, local sources do not fully meet the seed demand for all crops and farmers. LSBs are emerging trends in Uganda, increasingly providing quality seeds, especially for key crops like beans. CSBs also empower their members to produce and sustain seeds for certain crops. FGD participants also observed a decline in off-farm sources for RTB crops due to rising plant diseases, with formal sources underinvesting in these crops despite the high demand for disease-resistant varieties and quality planting materials. Our analysis of local seed sources underscores the diverse nature of Uganda's seed system, characterized as pluralistic seed systems — diversity of varieties and crop species and the involvement of various actors in seed production and dissemination of these, as discussed in section 3.2 of this report.

3.4.2 Seed security parameters by source

3.4.2.1 Availability

Seed availability refers to the overall supply and abundance of seeds within a farming community, considering seed production, storage, and the presence of seeds of diverse varieties. Typically, the quantity and diversity of seeds saved by farmers, stored in community seed banks, available in marketplaces, and local community gauge availability. Ideally, these seeds should be sufficient and available at the right time to meet the needs of farmers (85). In our study, farmers indicated the availability of seeds for their key crops from various sources, categorizing them as always available in sufficient quantity, sometimes in insufficient quantity, or rarely available in adequate amount. Figure 6 illustrates the number of FGDs that rated the seed availability of their key crops using these categories across different seed sources.

In our qualitative analysis of information from FGD participants (Figure 6), own farm-saved seeds emerged as the top source for seed availability, rated by 8 out of 13 FGDs as always available in sufficient quantity. Farmers prioritize their farm-saved seeds due to their reliability and availability, especially for perishable materials like sweet potato vines, cassava cuttings, and banana suckers. According to FGD participants in Soroti and Sheema, farm-saved materials for crops with perishable planting materials are also crucial because they enable farmers to avoid the risk of using diseased planting materials from other sources, requiring them to prioritize their availability from own-saving at home. The local market is rated by 5 FGDs, as always available in sufficient quantity. Market-based seed sources, including the local market, typically received low ratings for bulky RTB planting materials like banana suckers. The availability problem for RTB planting materials from market-based off-farm sources is primarily due to the logistical challenge of transporting them over long distances.

Moreover, farmers expressed that they cannot meet all the diversity they need with the seeds they save themselves and buy from local markets, leading them to rely on other sources. Many FGDs rated seed availability from sources like social networks (7 FGDs) and agrodealers (4 FGDs) as "sometimes available in sufficient quantity," which complements their own savings and local market to make seeds available for farmers. Still, social networks may not fulfill farmers' needs for the quantity of seeds of different crops and varieties they need. For instance, FGD participants in Hoima said seeds are occasionally available from social networks. Nonetheless, surplus seeds are sometimes

sold to traders, making the seeds farmers need for planting from this source unavailable. Similarly, in Soroti, FGD participants highlighted that the demand for seeds, e.g., cassava cuttings, often surpasses the availability of desired varieties from their savings and social networks. This sometimes leads to the exchange of immature cuttings among farmers, often cash-based, resulting in poor propagation and yields.

Seed availability from the government was rated the lowest, with the seeds rarely available in sufficient quantity at the planting time and unreliable supply. As new entrants in the Ugandan seed systems, CSBs and LSBs were appreciated by farmer groups mainly due to their proximity and timeliness; however, their capacity to meet the demand is still low.

3.4.2.2 Quality

The notion of "seed quality" differs between formal and informal actors in seed system literature. Formal actors emphasize standards that prioritize genetic purity (including distinctness, uniformity, and stability), high vigor, robust germination rates, absence of physical damage and impurities, and freedom from weed seeds, pests, and diseases, and seed certification is obtained from the regulatory agency that provides certification for quality assurance (85). In the informal

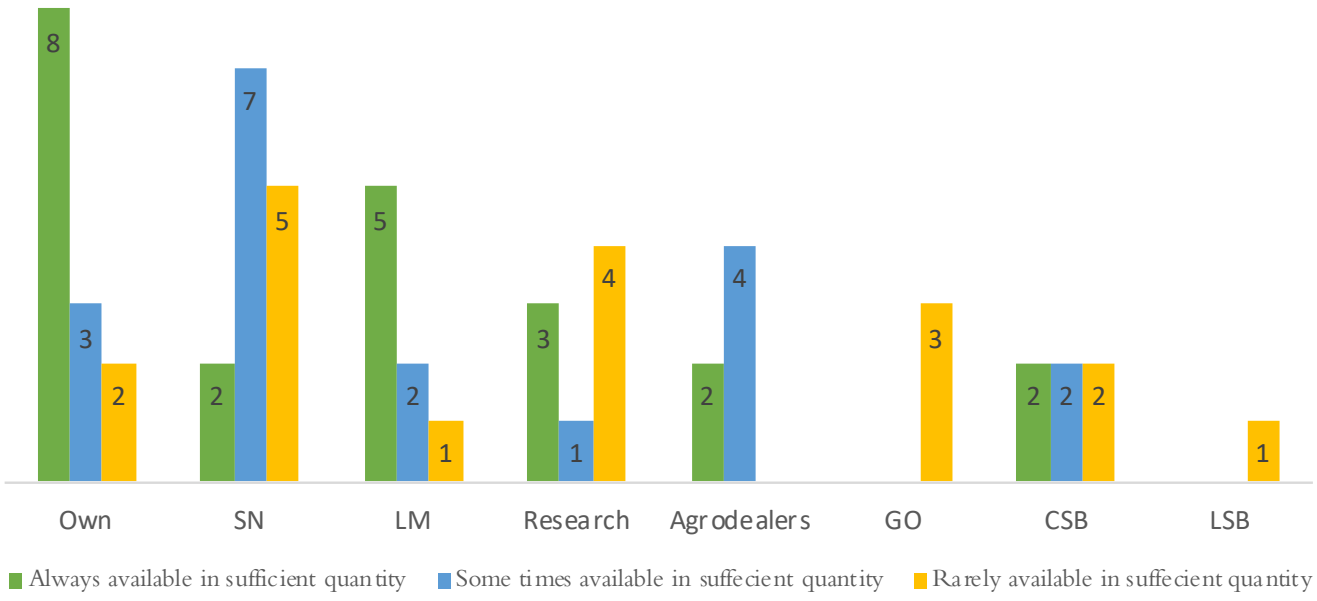


Figure 6. Number of FGDs rating seed availability of their key crops by source. The seed sources included own savings (OWN), social network (SN), local markets (LM), agricultural research centers (RESEARCH[10]), agrodealers, government seed subsidy programs (GO), community seed banks (CSB), and local seed businesses (LSB). Some FGDs provided ratings for seed availability, while others did not, explaining differences between Table 7 above and Figure 6 regarding identified seed sources.

10 During the validation of this report at a roundtable meeting in Kampala in April 2024, breeders cautioned against regarding research institutes as seed sources. While farmers appreciate the seeds of trial material they receive from these institutes, the materials they obtain are not part of any formal seed production and distribution scheme mandated for these institutes, according to breeders. These materials can be multiplied and reach a big scale over time as part of farmers' seed systems. However, it does not mean that research institutes are seed producers and distributors. Instead, the seeds provided are trial materials, and farmers continue to use seeds saved from on-farm trials due to the absence of an effective mechanism for withdrawing trial materials in Uganda.

system, other factors are often given more weight, and quality is commonly perceived in terms of yield, local adaptation, multi-use values, and trust in the seed source. Seeds from reliable sources are trusted for their credibility, while knowledge about seed varieties is also valued in determining quality (86). In this research, we asked FGD participants across all study sites to rate seed quality from various sources (Figure 7).

Seeds obtained from farmers' farm savings gained high-quality ratings across all study sites, primarily due to the trust in the stability and germination of their planting materials despite occasional varietal impurity. During the validation of this report at the roundtable meeting in Kampala in April 2024, breeders expressed skepticism about farmers' perceptions of seed quality, trust, and seed prices. They suggested that while certified seeds aren't costly in Uganda, farmers lack information about variety development and seed production costs. Additionally, they lack knowledge of the benefits of quality seeds. More importantly, a deep-rooted mistrust and resistance to change regarding seed purchases and the use of quality seeds of improved varieties, and overreliance on traditionally farm-saved is the problem, as one breeder doubted the trustworthiness of information provided by farmers:

> "Do farmers truly place more trust in the seeds they save themselves over certified seeds from alternative sources? If they doubt certified seeds from agrodealers, why do they complain about the absence of free certified seeds from government subsidy programs, such as OWC? They often lament not receiving free seeds from OWC. Why distrust the same quality seeds when available for purchase from agrodealers, yet accept them for free? This inconsistency raises questions about the reliability of farmers' trust-related concerns about the quality of certified seeds from agro-dealers."

Despite trust in their farm-saved seeds, farmers may still opt for certified seeds for commercial crops because of the required varietal purity for marketing and better price, unlike crops grown for household food consumption where the varietal mixture is acceptable, according to breeders who participated at the roundtable meeting in Kampala for validation of this report in April 2024. Equally, seeds sourced from social networks, including trusted families, neighbors, friends, and those from research stations, CSBs, and

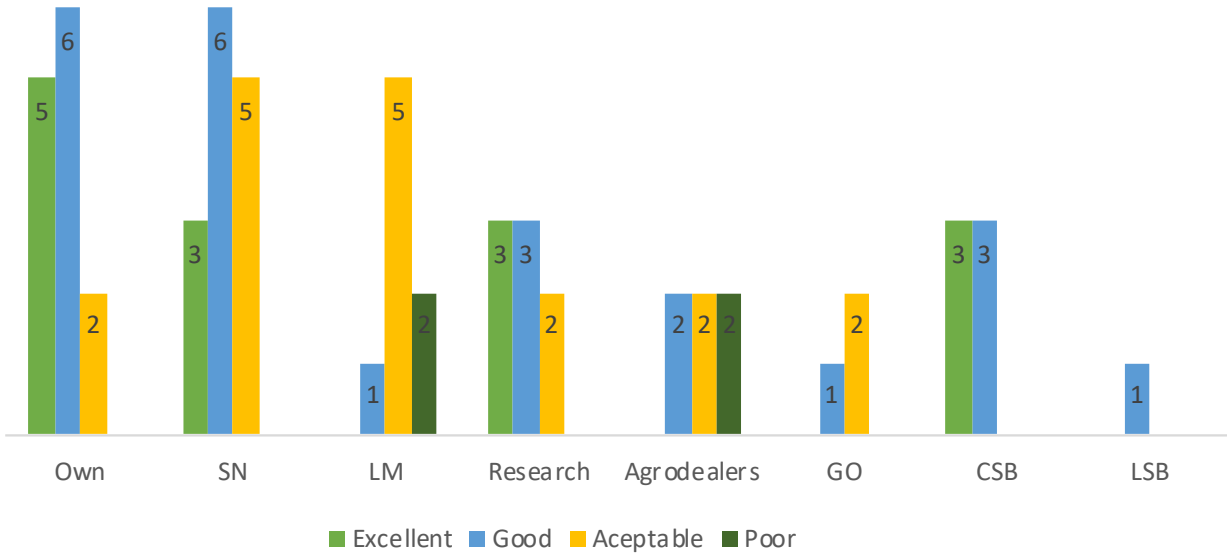


Figure 7. The number of FGDs rating the seed quality of their key crops by source. The seed sources included own savings (OWN), social network (SN), local markets (LM), agricultural research centers (RESEARCH), agrodealers, government seed subsidy programs (GO), community seed banks (CSB), and local seed businesses (LSB).

LSBs, were considered good, albeit with lower quality rankings than own seeds due to reliability issues such as germination rates. On the other hand, seeds from agrodealers, local markets, and government schemes received lower quality ratings due to reported issues like low germination rates and varietal impurity, indicating potential problems with "fake seeds."

Notably, CSBs, research stations, and LSBs received better ratings than commercial seed sources, following farmers' farm-saved seeds and social networks, indicating their growing importance in farmers' seed choices. For instance, farmers reported that CSB in Kabaale, Hoima, and Sheema is a source of seeds for local and modern varieties, thoroughly sorted, labeled, and stored in well-maintained facilities by trained farmers, thus providing high-quality seeds that have good germination, are free from pests and diseases. It is worth noting that farmers value research stations for the seed quality of trial materials they received, showing the significance of PPB/VS as channels for disseminating quality seeds from the formal system. Farmers in Hoima appreciated seeds from research stations for their excellent germination rates, high yields, well-sorted varieties, and training they received about the agronomic practices for growing varieties, enhancing their trustworthiness as a seed source. However, breeders caution that research institutes are not mandated to produce and distribute seeds; hence, they are not seed sources. Across all study sites, farmers mentioned poor storage facilities and variety sorting practices as major seed quality problems.

3.4.2.3 Access

Access to seeds comprises farmers' ability to acquire them through purchase, exchange, loan, or social networks. Farmers' ability to access seeds depends on several factors. These factors include affordability, capability to use social networks, physical access to seed markets (e.g., proximity to suppliers and transportation infrastructure), and extension services, including awareness of available varieties with desirable traits and seed types from different sources and seed prices. These factors determine how much seed farmers can access and whether they meet their needs (85, 87). This study explored farmers' seed access methods across diverse sources and transaction practices. Male and female FGD participants from the four study sites shared insights into how they acquire seeds for their key crops from various sources using different transaction types. The summary of their discussions is presented in Table 8 and Figure 8.

To estimate the distribution of transaction types, we documented the main crops identified in each site during the men's and women's FGDs and the associated seed sources and transaction methods used for each crop. Our analysis, illustrated in Figure 8, indicates that despite limited access when transactions involve cash, especially for poor farmers, cash-based seed transactions remain common in Uganda. While high prices from agrodealers, limited seed varieties they sell, and their distant location contribute to access limitation, cash transactions prevail, even within social seed networks, except in government and humanitarian programs due to free seed distribution. Additionally, transactions at agrodealers and local markets predominantly involve cash.

Several contextual variations regarding seed transaction methods exist across sites and key crops. In ***Kabaale***, accessing seeds presents varying ease and difficulty across different sources, as male and female FGD participants reported. Social networks emerged as highly accessible channels where farmers engage in diverse practices such as gifts from parents and close relatives, cash transactions, and bartering, facilitating collaboration among farmer peers. As reported by FGD participants, many farmers established alliances where one party provided land while the other supplied seeds, adopting collaboration through special crop-sharing agreements, thus facilitating seed access. On the other hand, they reported that access to certified seeds of beans and Irish potatoes from agrodealers in Kabaale is challenging due to the relatively high prices, rendering them less accessible, particularly for farmers facing financial constraints. Research organizations like Kachwecano Research Station under NARO engage farmer groups for on-farm trials and evaluation and provide the materials for free during field trials. CSBs provide accessible seeds through loans, gifts, and purchases, offering to both active members and some non-members based on available seeds. However, humanitarian organizations provide seeds primarily during crises, providing supplementary but inconsistent access

to seeds for financially constrained farmers. FGD participants elaborated that farmers encountering the most challenges in accessing seeds from agrodealers are those with limited financial means. Similarly, non-members of CSBs face hurdles in obtaining seeds, as they are required to make cash payments, unlike active members who can access seeds through loans or gifts during times of need.

In ***Hoima***, access to plant materials for the key crops - maize, beans, and cassava- varies across different sources. Social seed networks offer seeds through diverse means of access, such as gifts, loans, barter trade, and purchases with cash. Research stations like Bulindi ZARDI provide free seeds for research purposes without engaging in marketing. Agrodealers and local markets primarily transact in cash, but the agrodealers charge higher prices, up to 50,000 UGX

Table 8. Seed access rating from various seed sources based on transaction types.

Source of seed	Transaction types	Seed access rating
Own seed	No transaction	Highly accessible
Social networks	Gift, loan, barter trade, cash, and seeds in exchange for labor	Seed is very accessible due to the array of transaction methods and information available to obtain desired varieties within proximity.
Local Markets	Cash	Seed is not highly accessible due to household distance to the local market, limited variety types, limited information about varieties and seed quality, and affordability constraints.
Research stations	Free	Seed is not highly accessible due to inadequate quantities and a prolonged duration required for on-farm trial participants (often few farmers) to multiply and share seeds within the community. Breeders do not identify research stations as seed sources, but farmers appreciate these sources.
Agrodealers	Cash	Seed is not highly accessible due to limited diversity in seed varieties, uncertainty regarding the authenticity of seed quality and information related to varietal traits, and high certified seed prices that make it unaffordable for many.
Government schemes	Free, subsidized price	Seeds are not highly accessible because few varieties are available, seeds of these varieties are produced in insufficient quantities, and seed delivery is often delayed.
Humanitarian organizations	Free	Seed is not highly accessible due to the distribution of limited diversity, which may not always align with local agroecological conditions and farmers' livelihood needs. Additionally, it targets specific groups, and delays in supply further impair accessibility.
Local Seed businesses/ cooperatives	Cash	Seed is moderately accessible due to the source's proximity to the farming community it serves. QDS seeds of different size packages (3, 5, and 10kgs) are distributed to farmers. However, distribution or selling beyond the community is prohibited. The source offers a limited diversity of QDS, comprising only improved varieties. Farmers perceive the price as high but not as excessive as agro-dealer seed prices for certified seeds.
Community seed banks	Seed loan with interest, gift for members with problems, and cash	Seed is highly accessible due to its proximity to member farmers and the mode of transaction, which does not necessitate immediate cash payment. Additionally, it offers a relatively high diversity of crops and varieties— both improved and local.

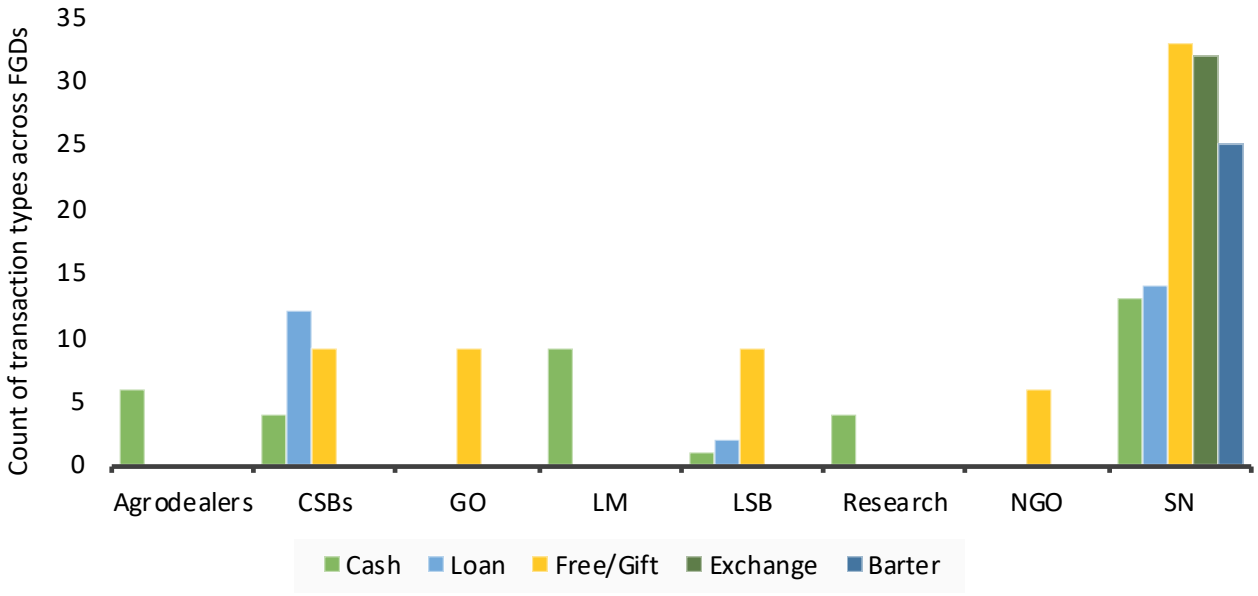


Figure 8. Farmers' seed access methods and transaction practices. The seed sources included agrodealers, community seed banks (CSB), government seed subsidy programs (GO), local markets (LM), local seed businesses (LSB), agricultural research centers (Research), Non-governmental humanitarian organizations (NGOs), and social network (SN).

per kg for hybrid maize seeds. Farmers noted that acquiring certified seeds, e.g., hybrid maize from agrodealers, entails additional costs like fertilizers and pesticides, making certified seeds of improved varieties more expensive, and farmers often decide to resort to local open-pollinated varieties (OPVs). Although the demand is high due to its lower price than the hybrid, agrodealers usually lack diverse open-pollinated maize varieties, limiting farmers' access to desired varieties. Access to seeds from the CSB is easy in Hoima but insufficient to meet farmers' needs, especially non-members. Access to seeds in Hoima is challenging for farmers with financial constraints such as landless and women-headed households.

In ***Sheema***, beans and bananas are key crops, and local farmers rely on social seed networks as their primary source of seeds. These networks facilitate access to seeds through various means, such as gifts, loans with interest, or cash transactions. According to the FGD participants, access to bean seeds is generally good in Sheema, with local markets, agrodealers, and LSBs offering reasonable prices compared to other regions. CSBs in Sheema operate on a loan system for members and cash payments for non-members, providing seeds at affordable prices. Farmers with financial constraints in Sheema encounter difficulties accessing seeds, particularly when purchasing certified seeds to change or renew their seed stocks or varieties. It is also challenging to find disease-free options for bananas in the area.

In ***Soroti***, social seed networks are crucial in accessing seeds for key crops like cassava, groundnuts, and sweet potatoes through various transactions, including cash sales, barter trade, and gifts. Groundnut seeds are priced between 3000 UGX and 7000 UGX per kg, and cassava cuttings cost between 15,000 UGX and 20,000 UGX per 50 kg bag, which farmers find affordable. Local markets and agrodealers also offer reasonably priced potato vines in Soroti. Research stations provide free seeds, with cassava cuttings priced similarly to those from social networks. CSBs grant access through loans with interest, while farmer cooperatives engage in contract farming with seed businesses or companies, retaining a portion of the seed for use at a reasonable price as an incentive, though limited to trained seed producer farmers. LSBs are crucial for vegetatively propagated materials like cassava and sweet potato in Soroti, charging around 50,000 UGX per 50 kg bag, which is not affordable for many poor farmers. Government and NGOs occasionally distribute free seeds in Soroti,

sometimes facilitating contract farming with farmers to multiply seeds for local distribution, easing access. However, farmers with limited financial resources face challenges accessing seeds from agrodealers and LSBs due to high prices.

Farmers' groups with difficulty accessing seeds and strategies to support them

Overall, in all four study sites, diverse groups, including the poor, elderly individuals, persons with disabilities, those battling alcoholism, casual workers, and the youth, encountered challenges in accessing seeds, according to FGD participants. The youth, constrained by limited land access, exclusion from cooperatives, and financial constraints, faced additional hurdles due to negative stereotypes such as perceived laziness, hindering their access to seeds from social networks. Similarly, persons with disabilities encountered discrimination, limiting their mobility and access to seed markets, while widows experienced marginalization due to land disputes, impeding their participation in seed-related initiatives. Likewise, women struggled to access farm inputs and reserve seeds due to irresponsible spouses and financial constraints. To tackle these challenges and improve seed accessibility, FGD participants have proposed several strategies for the future. Youth initiatives could involve parents or relatives leasing land for seed multiplication, facilitating their participation in seed value chains. At the same time, the government, humanitarian organizations, and other actors, including friends, relatives, and their children, should target older people for seed aid. Impoverished women resort to labor for seed funds or sell crops for seed acquisition, with relatives sometimes assisting in land leasing for planting to ensure food security. Disabled and landless individuals heavily rely on support from friends, family, and the government to access seeds, underscoring the importance of community and institutional assistance in ensuring equitable access to seeds.

3.4.2.4 Varietal suitability

A diverse range of crop species and varieties is indispensable to meet farmers' varied needs and preferences in crop production. No single species or variety has a full range of adaptations to environmental factors such as climate (temperature, moisture, light) and soil conditions (moisture, texture, acidity, salinity), as well as producers', farmers', market, and consumer preferences (88). In this regard, we emphasize varietal suitability as a crucial element within this context of seed security. Varietal suitability covers agronomic and quality traits tailored to meet farmers' specific requirements and preferences. These traits include yield, storability, marketability, resilience to environmental stresses, pests, and diseases, and alignment with culinary and cultural preferences (85).

The 4-Cell method

In our study, we employed a four-cell analysis method to assess the varietal diversity, quantity, and distribution of two key crops chosen by farmers at each study site, totaling eight selected crops in the four sites. This method entailed participatory discussions with male and female focus groups to classify varietal diversity for each key crop into five groupings: varieties grown in large areas by many households (LA-MHH), in large areas by few households (LA-FHH), in small areas by many households (SA-MHH), in small areas by few households (SA-FHH) and locally abandoned varieties. The criteria used for classification were based on the average areas defined locally as small or large and the number of households defined as few or many cultivating each crop variety. Although the average farm area and number of farmers they defined varied by crop and site, this allowed participants in the focus group discussions to share their perspectives on crop diversity, cultivation patterns, and community preferences within the areas under study (Figure 9).

Total intraspecific diversity of key crops

Our 4-cell analysis uncovered the diverse array of crop varieties cultivated by farmers in their communities. The analysis presents a high intra-specific diversity comprising 246 crop varieties across eight key crops in the four study sites, as depicted in Table 9. The counts for each site represent unique varieties identified by farmers with their local names after eliminating duplicate names mentioned by men and women FGDs across sites. It is important to underline that farmers in the different study sites may have used different names for the same variety and, on the contrary, assigned identical names to different varieties. Farmers were

Figure 9. The four-cell method was used to conduct a participatory assessment of the abundance (richness) and distribution (evenness) of key crops selected in the study sites. The first cell (upper left) illustrates varieties cultivated by many households in large areas, while the second cell (upper right) represents crops grown by a few households in large areas. In contrast, the third cell (bottom left) denotes varieties grown by many households in small areas, and the fourth cell (bottom right) denotes crops cultivated by few households in small areas. The dark rectangle indicates locally abandoned varieties in the area. The delineation of each axis reflects the consensus of male and female FGD participants at each study site. Drawing: Gloria Otieno

also sometimes unsure about the names of varieties. This poses a challenge in determining the uniqueness of each variety unless genetic analysis using DNA-based technology is employed.

Beans have the highest diversity across three sites, comprising 129 named varieties and 52 % of the varietal diversity of all eight selected key crops selected in different sites (Table 9). Beans are considered a crucial protein source and staple food in Uganda, a particularly popular staple in western regions, notably in Sheema, Kabaale, and Hoima. Furthermore, beans play a significant role in household income generation. Women specifically emphasized cultivating diverse landraces, farmers' varieties, and improved bean varieties with varying maturity times—long, medium, and short-term — to ensure prolonged household food security due to the staggered maturation of different bean varieties. Farmers also strongly prefer certain varieties, valuing their culinary and cultural significance.

Bananas exhibit high diversity in Sheema — 38 varieties, mainly landraces (Table 9) — valued for household food consumption and their functional traits like leaves suitable for wrapping and steaming food, such as matooke and banana bark used in basket weaving. Certain varieties are also appreciated for their taste and cultural significance during events like marriage ceremonies, contributing to the sustained cultivation of diverse banana varieties. Cassava is critical in food security, particularly in Hoima and Soroti, due to its preference for more extended food security periods in Uganda's relatively drier regions. Farmers strategically maintain diverse landraces and improved cassava varieties, ensuring household food security and meeting various culinary needs. According to FGD participants, the improved cassava varieties have better disease resistance, higher yield, and a short maturity period. This explains farmers' adoption and cultivation of these varieties in drier regions.

Table 9. Summary of intra-specific diversity of 8 selected key crops in four study sites. The number of varieties represents the sum listed by male- and female-focused groups at each site for their selected key crops (compare with Table 4).

Key crops	Hoima	Soroti	Sheema	Kabaale	Total
Beans	31		53	45	129
Banana			38		38
Cassava	13	12			25
Groundnut		18			18
Sweet potato		13			13
Irish potatoes				10	10
Maize	9				9
Sorghum				4	4
Total	53	43	91	59	**246**

Variety abundance/richness and distribution/evenness of key crops in the study sites

Using the 4-cell analysis, we evaluated the status of different varieties of key crops based on farmland allocation and the number of farmers growing them. We identified locally abandoned varieties, i.e., varieties that have disappeared or are rare/declining in prevalence. The analysis aimed to uncover the overall varietal suitability through reasons for the varietal changes, including market forces, agronomic traits, and culinary preferences.

In our analysis, varieties were classified based on farmers' reasons for their current extent of cultivation or abandonment (Annex 1). Our findings highlight that a significant proportion of the crop varieties farmers use consists of landraces and old improved varieties managed in their seed system. For example, the primary bean varieties of significance in Sheema and Hoima are improved cultivars known locally as Nambale long and Nambale short, released in 1994 by the National Crops Resources Research Institute in Namulonge as K131 and K132. These bean varieties are widely cultivated by numerous households in large areas, serving as essential sources of food security and income generation. The same scenario applies to banana diversity, wherein the most common variety, Entaragaza, was released over 20 years ago and persists as the top-rated variety in terms of market, agronomic, and culinary characteristics. In Soroti, farmers have identified 18 varieties of groundnut and 13 varieties of sweet potato, making these crops the most diverse after beans, bananas, and cassava. Irish potatoes, maize, and sorghum exhibit lower varietal diversity, with 10, 9, and 4 counts, respectively, despite their crucial role in ensuring food and livelihood security in the study areas. Farmers cultivate few commercial varieties of Irish potato and maize, while all named sorghum varieties in Kabaale are landraces, as the breeding priority for this crop is generally limited and existing improved varieties lack local consumption preferences (17). However, farmers primarily maintain sorghum landraces that perform better than others (Table 9; Figure 13).

A site-by-site analysis reveals that in Hoima, a higher diversity of maize used by farmers is improved varieties, and only two landraces are grown for their culinary characteristics. There is also a high diversity of beans, with many landraces cultivated by farmers for their desirable agronomic, culinary, and market traits. There are also "old improved varieties" of beans with suitable agronomic (especially their high yield) and culinary characteristics, making them very persistent in the seed system (Figure 10a).

In Hoima, nearly half of the cassava and six bean varieties have been locally abandoned. Only a few households cultivate many of the bean varieties in

small areas, putting them at risk of local abandonment and highlighting the urgent need for conservation efforts (Figure 10b).

In Sheema, there is a remarkable diversity of beans and bananas identified by both men and women farmers as their most important crops. Despite this high diversity, only a small percentage of the improved varieties come from the formal sector (Figure 11a). For beans, 'old improved' varieties comprise 70% of the diversity farmers use, while landraces account for about 17%. This highlights the crucial role of bean landraces in farmers' food systems in Uganda (Figure 11a).

An analysis of the status of varietal suitability in Sheema shows a high amount of diversity in beans and bananas grown in small areas by a few households and kept mainly for their culinary traits. There is also a considerable diversity of both crops that are locally abandoned (Figure 11b).

Farmers have identified 18 groundnut, 13 sweet potato, and 12 cassava varieties in Soroti. These crops were the most diverse after beans and bananas,

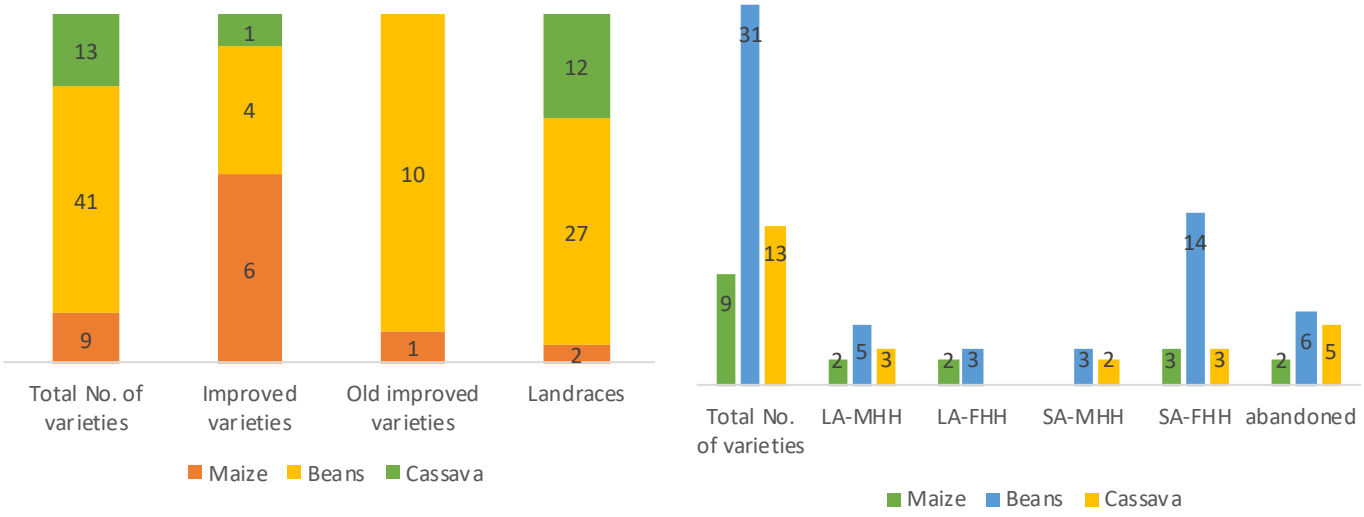


Figure 10. (a) The number of named varieties, including old improved and landraces managed in farmers' seed systems, alongside certified seeds of improved varieties obtained from the formal sources for each key crop in Hoima. (b)The number of key crop varieties classified into different 4-cell categories in Hoima.

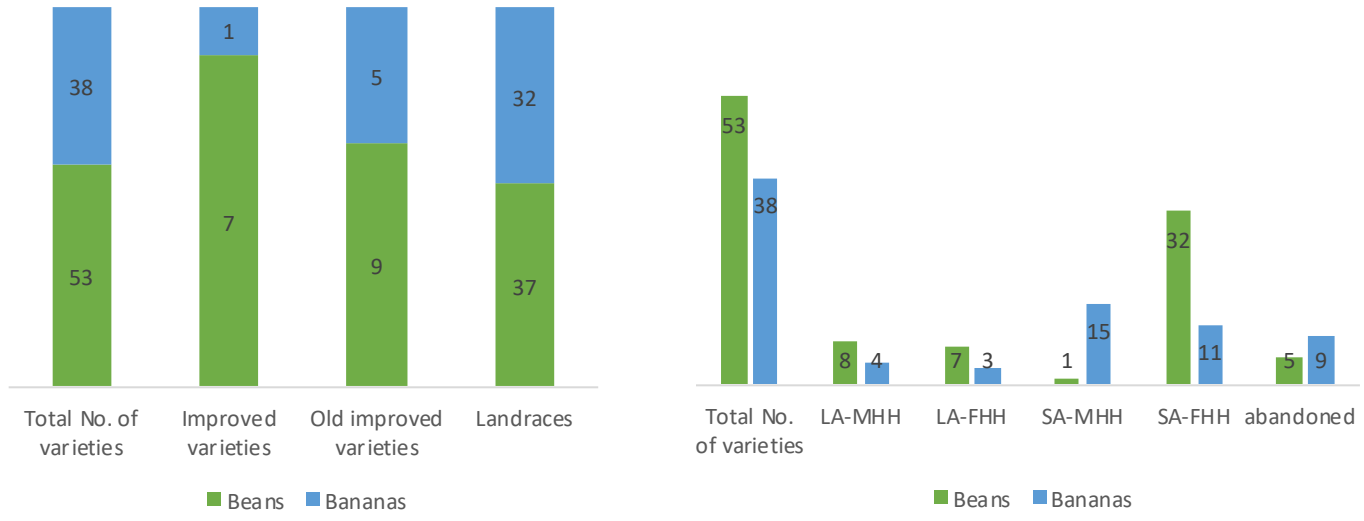


Figure 11. (a) The number of named varieties, including old improved and landraces managed in farmers' seed systems, alongside certified seeds of improved varieties obtained from the formal sources for each key crop in Sheema. (b) The number of key crop varieties classified into different 4-cell categories in Sheema.

which farmers identified as key crops across all study sites. Groundnuts in Soroti display a high diversity of improved varieties, including recently released ones with excellent traits and high productivity (Figure 12a). On the other hand, sweet potatoes are mainly landraces, produced and exchanged through social networks. Cassavas, identified as a key crop by both men and women in Soroti, are valued for household food security. Many cassava and sweet potato landraces are grown by a few farmers in small areas, and many others are already locally abandoned in Soroti, indicating their possible loss (Figure 12b).

In Kabaale, farmers largely depend on landraces, particularly for beans, which constitute 71% of the varieties farmers use. In Kabaale, there is no improved sorghum that farmers identified, and the few varieties farmers cultivate are landraces. There is also a heavy reliance on landraces for Irish potatoes (Figure 13a). A standout finding in our analysis of Kabaale is that much of the bean diversity is either grown by a few farmers in a small area or locally abandoned. This finding underscores the need for variety replacement and conservation intervention to preserve bean genetic diversity (Figure 13b).

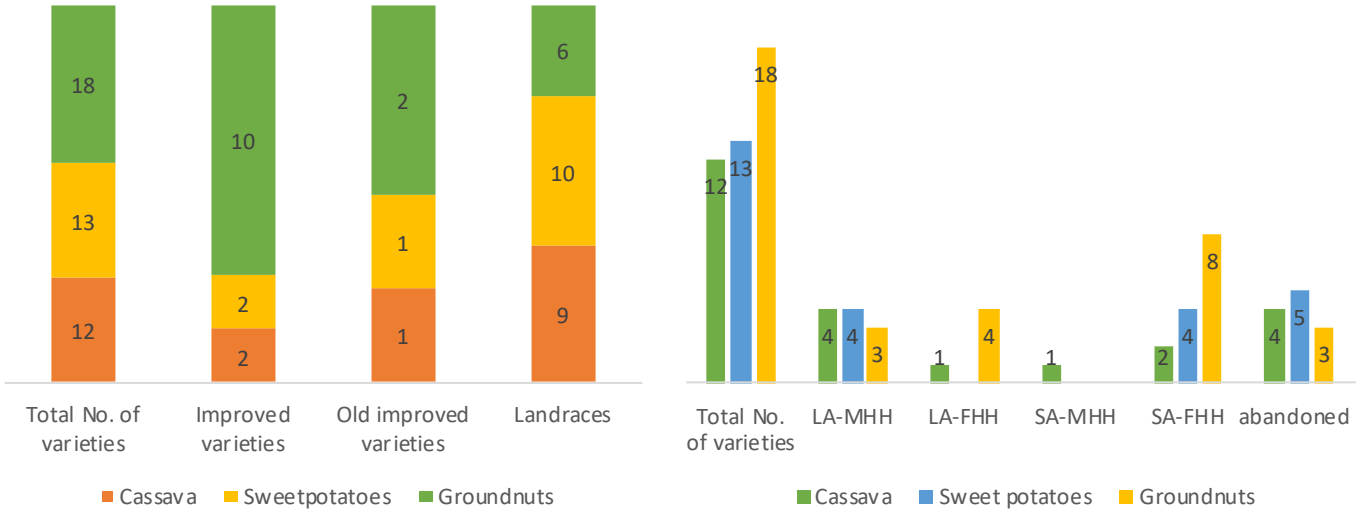


Figure 12. (a) The number of named varieties, including old improved and landraces managed in farmers' seed systems, alongside certified seeds of improved varieties obtained from the formal sources for each key crop in Soroti. (b) The number of key crop varieties classified into different 4-cell categories in Soroti.

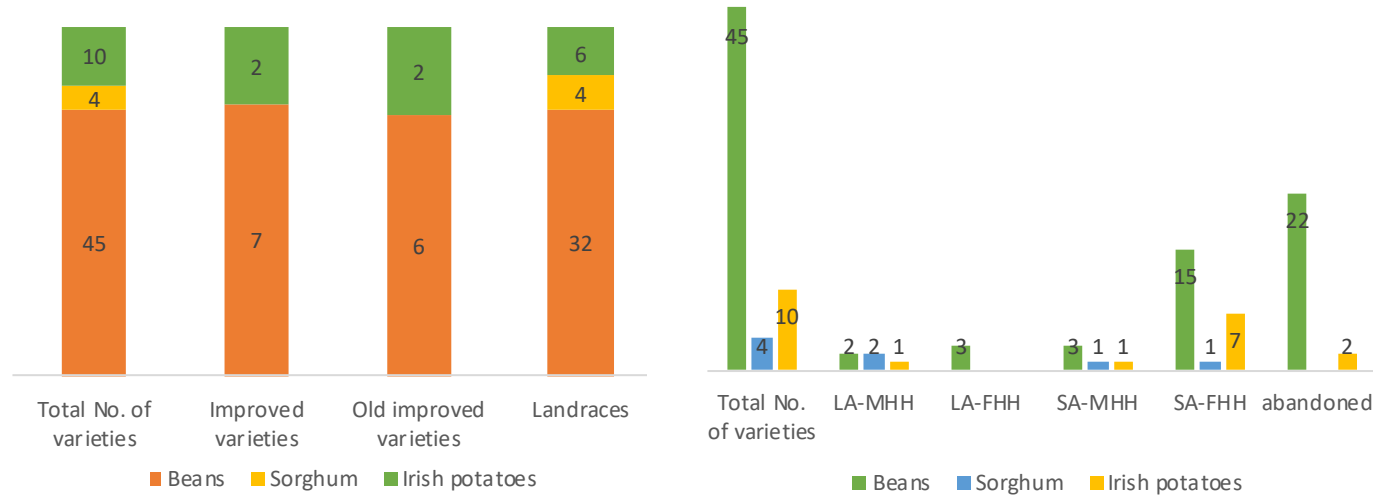


Figure 13. (a) The number of named varieties, including old improved and landraces managed in farmers' seed systems, alongside certified seeds of improved varieties obtained from the formal sources for each key crop in Kabaale. (b) The number of key crop varieties classified into different 4-cell categories in Kabaale.

Overall, we observed that the commonly grown varieties found over large areas by many households consist of many improved varieties. These varieties serve dual purposes of income generation and food security. For example, commercial and old improved varieties of maize and groundnuts, known for their high yield and market acceptance, dominate this category. Varieties cultivated over large areas by a few households are also predominantly improved, often possessing unique agronomic qualities tailored to specific market needs. For example, popcorn varieties are grown by a few farmers residing near schools and towns where electricity and skilled vendors are available for popping, requiring specialized techniques such as maintaining standard kernel moisture.

Varieties grown by many households in small areas are numerous and valued for their diverse household consumption attributes, such as cooking time and culinary traits. Similarly, varieties cultivated in small areas by a few households share similar characteristics with those grown by many households but in a smaller area. For example, localized improved varieties and sweet potato and cassava landraces dominate these two categories in the studied areas. However, most abandoned or lost varieties are landraces. Much of this diversity is abandoned due to inadequate agronomic, culinary, and market traits. The high number of abandoned crop varieties highlights the need for urgent actions to replace them with new varieties through breeding programs or collaborations with genebanks and other stakeholders in the seed system. These interventions can help reintroduce and improve the performance of landraces, using proven experiences and strategies to reduce the depletion of available genetic resources (89).

Varietal traits affecting abundance and distribution.

According to FGD participants, various factors influence the abundance and distribution of key crop varieties in the study sites. These factors encompass varietal traits aligned with farmers' needs and preferences, such as yield, market value, disease and pest resistance, and early maturity. Additionally, farmers prioritize functional traits for culinary quality, cultural significance, and adaptability for multiple uses like soil fertilization, livestock fodder, and production of goods such as alcohol and furniture (e.g., ropes, baskets).

To better understand the factors involved in categorizing different varieties (improved and landraces) into the 4-cells or locally abandoned category, we asked the participants of the FGD to provide further elaboration. They were asked to consider both positive and negative traits and market, agronomic, and culinary features for all the varieties. A detailed summary of these traits is organized and presented in Annex 1. Here, we emphasize these factors, particularly highlighting the positive characteristics of popular varieties of a few key legumes, cereal, and RTB crops *cultivated by many households in large areas*. Additionally, we emphasize the negative traits contributing to the decline of varieties of these crops grown by few households in small areas and abandoned varieties. We note that varieties grown by many households in small areas generally display a mix of positive and negative traits. This observation also holds for varieties cultivated by a few households in large areas, with the distinction that these varieties are typically valued for their marketability.

Positive traits

That said, farmers in Hoima, Kabaale, and Sheema described many ***bean*** varieties grown by many households in large areas as "delicious, with a nice aroma, short cooking time, soft edible pods, high yielding, heavy seeds, large size seeds, and high market demand among traders and schools with children feeding programs." However, a few limiting factors were mentioned, such as expensive seeds, labor intensiveness (for climbing bean varieties), and susceptibility to heavy rain/hailstorms. Unique positive traits of widely cultivated ***groundnuts*** include ease of harvesting, drying, shelling, and pounding, high oil content, a sweet taste, and tolerance to drought conditions, as FGD participants in Soroti reported. Farmers highlighted positive traits for two popular ***sorghum*** landraces, Kyatanombe and Rwamabare, which were extensively cultivated by many households in Kabaale. These traits comprise high-yielding, nutritious, drought-resistant, marketable, versatile for culinary uses like porridge or karo, and suitable for local alcohol brewing. However, their tall height and long maturity make them vulnerable to lodging and bird attacks. Similarly, farmers appreciated two open-pollinated improved varieties of ***maize*** for their high

yield and drought tolerance in Hoima.

Sheema area is home to a remarkable diversity of ***banana*** varieties, as shown in Figure 11. Through discussions with male and female focus group participants, it was revealed that three specific types of bananas are predominantly cultivated based on the perceived area allocated to the varieties and the number of households that grow them. Entaragaza and Kibuzi are improved varieties introduced over two decades ago and subsequently integrated into farmers' banana seed system. Enyeru is a variety that farmers have developed with the support of breeders and agronomists. These varieties are favored for their high yield, large bunch sizes, good cooking taste and texture, and high market value. Despite their attributes, they exhibit varying degrees of susceptibility to pests (banana weevil) and diseases (banana wilt) like many other varieties, with some being late maturing and challenging to peel when not fully ripe (like Kibuzi)

Farmers in both male and female FGD sessions shared interesting insights into the positive traits of the most popular cassava varieties grown by many households in Soroti. The variety known as Nigeria is valued for its dense weight, high yield, extended stay in the garden, suitability for food and market, and starch content utilized in detergent and pharmaceutical industries. However, consumption of premature cassava may cause nausea and vomiting for humans, and its leaves are poisonous for livestock. Similarly, the variety known as NAROCASE 1 is valued for its high yield, early maturity, and versatility in various marketable products, including flour, chips, bread making, and alcohol brewing. However, it is susceptible to fungal diseases and prone to rotting.

Negative traits

On the other hand, many varieties of the key crops are either abandoned or declining because only a few households are cultivating them in small areas. This decline is attributed to traits that do not meet farmers' needs and preferences, particularly concerning growing conditions, market demand, agronomic characteristics, and culinary requirements (Annex 1). FGD participants in Hoima, Kabaale, and Sheema emphasized the importance of marketability in sustaining and utilizing ***bean*** varieties, with abandoned and declining ***maize*** landraces in Hoima facing similar challenges of low marketability. It has been observed that a majority of ***bean*** varieties that are abandoned or declining lack market demand and exhibit unfavorable traits like low yield, poor taste, labor-intensive cultivation, weak tolerance towards weeds, dark seed color disliked by consumers, late maturity, poor edaphic adaptation (also called soil selectivity by farmers), and susceptibility to heavy rainfall. Despite Uganda's vast diversity of beans, many varieties are either abandoned or declining (Annex 1). For ***groundnut***s, the lack of drought tolerance and pest resistance are the primary factors contributing to the loss or decline of varieties. Soroti's widely grown varieties of groundnuts are vastly outnumbered by these declining ones, calling for an increasing diversity of suitable varieties.

Several ***banana*** varieties have been abandoned, according to male and female FGD participants in Sheema (Annex 1). Despite possessing certain positive traits, these varieties have fallen out of favor with farmers due to lack of market, low multiplication rate, hard texture requiring long cooking times, high susceptibility to banana weevil and banana wilt, low yield due to small bunch sizes, and inability to survive poor soils. The negative traits of abandoned and declining ***cassava*** varieties encompass difficulty in storage beyond six months, lack of drought tolerance and disease resistance, inedibility when consumed fresh, low yield and late maturity, and a labor-intensive preparation process for consumption.

Overall, the extensive infraspecific diversity of the key crops in the study sites offers farmers options tailored to their growing conditions, with each variety presenting a mix of positive and negative traits. Nonetheless, the alarming large quantity of abandoned and declining varieties necessitates conservation efforts, demand-led breeding to develop suitable varieties, the introduction of new diversity, and the restoration and enhancement of lost varieties from other sources, including neighboring communities.

4 DISCUSSION: THREE PROPOSALS FOR STRENGTHENING COLLABORATION AND SEED SYSTEM OUTCOMES

This discussion chapter outlines stakeholder views on three long-term proposals to enhance collaboration and coordination for improved seed system performance. Based on the previous chapters' characterization of seed system strengths and weaknesses and insights from these key seed system stakeholders at both local and national levels, we identified three proposals/strategies for enhancing Uganda's seed system performance in the long term: 1) Strengthen decentralized approaches to seed system development; 2) Establish multistakeholder platforms for crop genetic innovation and quality seed production and distribution; 3) Undertake capacity building initiatives at various levels to strengthen the seed system. In discussing these proposals, we reflect the different views of different actor groups.

4.1 Strengthen decentralized approaches to seed system development.

Most public and community-based seed system actors interviewed, both at the national and local level, including farmers, advocate for community-based and demand-led variety development, quality seed production, and effective seed distribution to enhance farmers' seed security in Uganda. They stress the importance of establishing new and supporting existing community-based actors in distinct agroecological zones, whether market- or non-market-based, to address the diverse needs for different crops and growing conditions. Additionally, they emphasize that public investment should target these actors through regular allocations in local government budgets, along with support from central government structures. Most of these actors argue that for Uganda to establish an effective seed enterprise independent of non-governmental organizations and donors, government-backed community-based actors must be the starting point and empowered to gradually enter the commercial seed sector when demand for specialization on specific crops arises. However, some commercially oriented stakeholders, such as seed companies, breeders, intellectual property rights advocates, and policy actors, argue that the community-based actors have not demonstrated effectiveness and sustainability in delivering quality seed and ensuring seed security other than distorting the seed market, which contributes to discouraging private investment (see quotes in section 3.2.2 regarding this skepticism about the quality of seeds at the CSBs).

Advocates who support investing in community-based actors disagree with those concerned about farmers' capacity for quality seed production. They point out that farmers have valuable local knowledge, and those local seed entrepreneurs, such as LSBs, have had successful outcomes during the past decade in Uganda. Additionally, they believe that private actors are generally not interested in Uganda's food security crops, and therefore, skepticism about community-based seed production is unfounded and biased. However, various actors' differing perspectives on seed system development are awakening and relevant to future debates about Uganda's current pluralistic approach to seed system development.

4.2 Establish multistakeholder platforms.

Several key informants from the national genebank, national plant breeding programs, and NGOs supporting LSBs emphasized the significance of formal collaboration among seed system actors. They stressed the establishment of a multistakeholder platform as a crucial strategy to improve Uganda's seed system performances in the long run. These platforms would integrate conservation actors, variety development and management actors within *crop genetic innovation*

and coordinate quality seed producers, inspectors, trainers, and different seed market outlets, including agrodealers and LSBs, under a dedicated *seed security innovation* platform.

In other words, these multistakeholder platforms were suggested to rectify coordination breakdowns among actors engaged in diverse seed system functions during cross-linkage exercises to identify coordination issues among key seed system actors in Uganda (Figure 4, 5, and Annex 2). Here, coordination refers to organizing the diverse components of the seed system or functions to optimize the efficiency of individual elements and the system, requiring strong governance through guiding and leading actions, along with mainstreaming institutional arrangements to ensure effective operations. Establishing clear priorities and plans through such platforms can benefit the different seed system actors and external supporters like NGOs and donors in the future. It can facilitate support for capacity-building among seed system actors while also serving as a channel for skill, knowledge, and information exchange.

4.2.1 Multistakeholder Platform for Crop Genetic Innovation

Plant breeders, private seed companies, LSBs, and supporting NGOs advocate for establishing a *crop genetic innovation platform* due to the inadequate availability and accessibility of improved varieties with high yield potential, climate resilience, and disease resistance. Additionally, the decline of landraces, as discussed in sections 3.1 and 3.4.2.4 across various crops, emphasizes the necessity for collaborative efforts among stakeholders for conservation and the base-broadening of crop diversity. In our analysis, we have identified potential key stakeholders for the crop genetic innovation platform. These include the NPGRC, NARO institutes and its affiliated zonal breeding programs (ZARDIs), Alliance of Bioversity International and CIAT, MaRCCI, UPHIA, NSCS, regional NAADS, and farmer research groups[11] across distinct agroecological regions. Other than public institutions like CGIAR centers, donors and NGOs supporting seed system actors' work can provide financial and technical support without necessarily being represented as permanent members in the coordination platform. While respondents did not specify which stakeholder could lead the proposed platform or its structure, most suggested a possible unit within NARO. Although NPGRC, being part of NARO, has the potential to lead such a platform, concerns still need to be addressed regarding its ability to coordinate activities with ZARDIs and farmer research groups regularly, for example, due to a lack of structure in the regions. In April 2024, during the roundtable meeting organized to validate this research report, participants underscored the crucial need to establish the platform. They also agreed that this is one of the issues that MAAIF should consider in connection with the ongoing discussion to reform the agricultural institutions (including the seed sector), such as establishing a new extension directorate, the Food and Agricultural Authority (FAA), a public or parastatal seed company, and redefining the roles of NRAO holding and NAADS.

The proposal to create a crop genetic innovation platform aims to speed up the development and availability of new varieties that are better adapted to different conditions. This includes selecting suitable varieties from existing improved varieties in different research institutes and landraces with better performances to increase availability through strong regional and national connections. Such a platform could be crucial if acknowledged and backed by the MAAIF. The proposed platform can help identify conservation and breeding priorities, develop joint plans, and harmonize interdependent stakeholders' activities (Annex 2) to deliver diverse crop varieties farmers prefer across Uganda's agroecological regions. Additionally, the platform can be tasked with digitizing information related to conservation and breeding priorities, developing joint annual and multi-year plans, and facilitating genetic resources, knowledge, and information exchange. For instance, it can facilitate integrated in-situ and ex-situ conservation

11 In this report, the *Farmers Research Group* represents a collective of volunteer farmers collaborating closely with a diverse multi-disciplinary research team, including breeders, plant pathologists, agronomists, and extension workers. They undertake collaborative research initiatives on specific issues or topics aligned with farmers' needs. This joint effort primarily occurs directly within farmers' fields, facilitating activities such as plant variety evaluation and selection conducted under authentic farming conditions.

activities and the distribution of preferred varieties to community-based seed multipliers for RTB crops at minimal cost. This entails coordinating activities and collaborations among farmer research groups, NPGRC, and MBAZARDI, which conserves a regional collection of bananas from five countries. Similar initiatives can be extended to cereals, legumes, and other crops, with farmer research groups, NPGRC, CGIAR centers, ZARDs, MaRCCI, and regional NAADS collaborating on implementation. If carefully planned, this approach will streamline efforts, expand farmers' choices, and mitigate conflicting information communication often encountered by farmers from various seed system actors promoting different varieties and seed types.

4.2.2 Multistakeholder Platform for Seed Security Innovation

Suggested key actors for the proposed seed security innovation platform primarily include the participation of seed producers and distributors. Private multinational seed companies were not part of the suggested potential actors for the platform since they focus only on a few profitable crops, have independent business models, and have the capacity to operate within Uganda's policy and regulatory framework. Governance constraints highlighted above, such as the absence of regulations, guidelines, and data outlined in the national seed policy and laws, must be addressed to ensure that the private sector operates in an enabling environment for seed production and marketing. Key informants, including NGOs, LSBs, and NARO, are enthusiastic about the emerging intermediate seed system with QDS production and marketing and emphasize the need to enhance community-based seed production and distribution to complement formal seed system actors' efforts. Based on this emphasis, the proposed seed security innovation platform can include LSBs, CSBs, NARO holdings, NPGRC, CGIAR centers, NSCS, and NAADs to facilitate quality seed production of diverse crops and varieties and effective distribution. For example, enhancing the coordination among these actors was perceived as a solution to combat the issue of counterfeit seeds, particularly by supporting community-based quality seed production and marketing efforts.

The vision for the proposed seed security innovation platform encompasses two key objectives. Firstly, it is believed that the delivery of quality EGS can be enhanced by coordinating demand and supply between certified and QDS producers and EGS suppliers. One of the main activities of this platform will be demand forecasting to facilitate planning for EGS production, i.e., basic or foundation seeds for different crops. This forecasting can be further done at the district level to facilitate the development of operational annual plans by aligning seed demand from farmers with production and distribution through registered marketing and non-market actors. However, for this to be fruitful, a mechanism for seed demand assessment must be developed. Secondly, the platform could facilitate a more effective quality assurance and certification scheme, ensuring compliance with existing laws and regulations. This involves organizing skill training for seed producers and assessing the required number of inspectors per seed class in different regions. To achieve these goals, the proposed platform would support digitalizing demand and supply, considering various factors such as agroecology, crops, varieties, and seed class while prioritizing openness, accessibility, and transparency (through digital seed tracking and tracing systems) for all stakeholders. Additionally, the platform would serve as a vital channel for information exchange, especially in connecting potential buyers with seed producers. The 'information and seed exchange' platform can allow seed producers to connect with various buyer categories.

However, key informants expressed uncertainty regarding the platform's structure and leading institution, suggesting that it should be housed by a unit under the MAAIF. During the roundtable meeting to validate this report, participants suggested that these could be an issue for discussion as part of the ongoing institutional reform in MAAIF.

4.3 Capacity Building

In this section, we outline capacity-building needs to enhance Uganda's seed system performance, which were identified by focus group discussions and key informants. The capacity-building needs are at two levels: local and national.

4.3.1 Local Capacity Building Needs

The FGD participants' and local key informants' perspectives underscore the need for comprehensive capacity-building support within seed production and dissemination. This includes supporting registered community-based seed producers and distributors with skill training, facilitating exchange visits for practical knowledge, providing financial support for startups and expansion, allocating farmland for seed multiplication, and establishing infrastructure such as irrigation, governance, and organizational management support. Additionally, the pressing need for timely inspection for seed certification, crop/seed insurance, and irrigation equipment highlights the diverse challenges and opportunities for capacity building within seed production. Regarding policy, NGOs and CSB groups call for support that acknowledges the registration of preferred farmers' varieties for marketing, alongside improved varieties, as a practical measure for capacity-building of community-based actors. Farmers and local actors also highlighted the importance of assisting with seed transportation and improving access to information for effective quality seed dissemination and utilization. These local capacity-building needs can be integrated into the plans for developing the platform for seed security innovation, as suggested in section 4.2.

Finally, there is a strong recommendation from NGOs, CSB, and LSB groups for the government to build local capacity to revitalize the vegetable seed value chain by creating locally adapted varieties, generating early-generation seeds, and connecting with local businesses for certified and QDS production. Development organizations such as NGOs expressed that ensuring the availability of high-quality vegetable seeds at fair prices for farmers is crucial, an assignment that government agencies should explore. Introducing local seed enterprises as producers of vegetable EGS was suggested as a promising approach to address the current shortage. Additionally, support for CSB was proposed so that it could take on an additional or more commercially oriented role in seed production and marketing by branding its seeds.

4.3.2 National Capacity Building Needs

Most key informants, both at local and national levels, emphasized the urgent need to enhance the human resource capacity of key national seed system institutions such as NPGRC, NARO, NSCS, UPHIA, and NAADS. This includes the establishment and staffing of UPHIA, which has not yet been done. It also involves training more genetic resource experts, breeders (for most crops where they are lacking), seed technologists, field inspectors, and others to strengthen the capacity of mandated institutions. Breeders and seed companies stress the importance of expanding breeding efforts to increase the diversity and quantity of improved varieties and early-generation seeds. To achieve this, implementing seed and PVP laws and associated regulations is essential for efficient variety release, quality control, and certification. Therefore, regulatory agencies are strongly urged to enforce these measures effectively. Nearly all stakeholders highlighted the NSCS's limited capacity for field inspections and the inadequacy of having only one seed testing laboratory for all seed producers and other service needs in the country. This hampers NSCS's ability to effectively oversee all seed producers, distributors, and fields. As a result, there is a notable weakness in enforcing seed laws for quality control across different levels, contributing to the proliferation of counterfeit seeds. In addition, implementing unbiased functional extension systems was suggested as a vital component of capacity building. As one of the key informants said:

> "Initially, extension services were monopolized by the public sector, exerting control over farmers by providing instructions based on scientific knowledge, mainly for commodity crops. Following independence, the government adopted an educational approach, establishing district farm institutes and transitioning towards a participatory model. The extension system is demand-driven, primarily serving commercial entities rather than small-scale farmers. This shift has led to the emergence of various actors, including NGOs, community-based organizations, and the private sector, providing extension services. As a public sector entity, we acknowledge the importance of involving these diverse actors in extension services while retaining our leadership role.[12]"

The suggestion entails formally integrating other key players into the extension system, particularly NGOs, research organizations, and select private sector companies, as they already play a helpful role in capacity building. Infrastructure, including research facilities, storage, transportation, irrigation, credit facilities, and tax reduction, is the next priority for national-level capacity building.

Finally, a comprehensive digital platform, including a database for information dissemination and exchange, was proposed to enhance the performance of the seed system actors. This was perceived to improve private actor participation, coordination, and collaboration, enhancing traceability, accountability, and technical support among seed system actors for improved efficiency and effectiveness. Here, the understanding is that open and collaborative relationships among actors are essential to overcome isolation and promote synergy.

12 Interview with a Senior Commissioner for Agriculture extension services and skills management, MAAIF, Entebbe, June 22, 2023

5 RECOMMENDATIONS

The findings of this study were validated and discussed at a final stakeholder roundtable meeting in Entebbe in April 2024. Based on the study results and the stakeholder discussion, three recommendations for short- to medium-term programmatic intervention to increase farmers' access to suitable varieties and quality seeds in Uganda were co-developed:

1. Support community-based and market-oriented seed production and distribution program

To increase the availability of and access to quality planting materials in Uganda, priority for short- to medium intervention could be given to establishing and supporting a network of community-based seed producers across crops and agro-ecologies with effective marketing channels. The specific actors to be targeted encompass LSBs run by individual and organized groups of farmers, certified RTB nurseries and mother RTB gardens run by enterprises, and CSBs that have begun producing QDS. Suggested areas of intervention include:

a. Improving availability and access to high-demand planting materials by farmers for registered improved varieties with limited seed availability

b. Increasing accessibility of preferred landraces and farmers' varieties with limited seed availability

c. Improving the quality of certified and QDS planting materials distributed or sold to farmers

d. Improve farmers' means of access to quality planting materials, such as credit, local seed storage facilities, and timely information on seed availability, varieties, and prices.

Interventions could serve as a pilot for learning and pave the way for the proposed multistakeholder seed security innovation platform proposed in section 4.2, aimed to provide long-term support for improving seed availability and access. This recommendation aligns with Priority Area 3.4.2 of the 2018 national seed policy, which focuses on establishing a Seed Sector Integrated Information Management System (SSIIMS). This could involve setting up a mechanism for regularly determining seed demand, creating a Management Information System (MIS) and web portal at NSCS to share critical seed sector information, and raising awareness about Uganda's diverse seed classes through practical communication tools. Specific suggestions for how this can be achieved are as follows:

i. Determine and establish a central stakeholder coordinator for a community-based seed producer and distributor network. Such a coordinator should have the endorsement and backing of relevant public and community-based actors and strong networking abilities to engage with local seed producers and distributors in Uganda effectively.

ii. Through the coordinator, create an open online communication and learning platform, incorporating a comprehensive database of actors (e.g., LSBs, CSBs), their focus crops (including available varieties where applicable), geographical coverage, seed production volume, quality standards, distribution channels or networks, as well as gaps, challenges, and operational requirements. In addition, the coordinator should integrate a digital seed tracking and tracing system to monitor seed movement from pre-basic to certified and QDS production stages and through sales (tracking). The platform should also contribute to certified and QDS seed demand forecasting in the future, building on existing similar initiatives (80).

iii. Utilize the platform/network to identify priority crops, varieties, and number of seeds that network members intend to produce in the short to medium term. Additionally, assess their capacity-building requirements for seed production and distribution among key network participants. Subsequently, resources from the government, donors, FAO's benefit-sharing fund, and community sources should be mobilized to provide necessary support through the coordinator and its partners.

2. Support conservation and demand-driven plant breeding program

Unlike seed production and distribution actors, which have increased in the last decade, actors in conservation and plant breeding are limited in Uganda. In addition to encouraging private sector plant breeding investment, a long-term program that invests in conserving existing crop varieties, especially those that are endangered or underutilized, and implements demand-driven variety development strategies is immensely needed to ensure continued availability of crop diversity that meets farmers' needs. This study also shows the importance of actively engaging farmers in participatory approaches to defining crop trait priorities and conducting participatory crop variety evaluations using strategies like the Tricot[13] method to address specific needs and preferences effectively. The proposed conservation and demand-driven plant breeding program can build on the following existing institutions and initiatives:

a. NPGRC can establish a functional platform for ex-situ conservation, germplasm multiplication, and characterization in Uganda. NPGRC can achieve this through collaboration and coordination with other conservation facilities and CSBs in the country. Such a platform will help to enhance performance by consolidating information on conserved material for both long-term use and short-term distribution to users. It also helps identify and document gaps across all conservation facilities and CSBs and links these actors using an online database they all use and contribute to. Furthermore, materials should be characterized, and information on their traits should be documented and available for farmers, breeders, and researchers. These materials can be utilized for high-tech and conventional plant breeding and participatory on-farm germplasm evaluation by breeders and researchers to deliver adapted varieties to farmers efficiently.

b. Through NPGRC's coordination, MBAZARDI, with its regional collection of 450 accessions of bananas from DR Congo, Kenya, Tanzania, Papua New Guinea, and Uganda, leads the work on RTB crops. MaRCCI holds 9548 accessions of cowpea and sorghum and a state-of-the-art ex-situ conservation facility, seed laboratory, and data management system, and it could enhance NPGRC's capacity (e.g., staff training) to conserve and utilize cereals, legumes, and other crops. The Alliance Bioversity International and CIAT house 3000 bean accessions and could join this capacity-building effort. Through these collaborations, the platform can attract donors and governments interested in building national capacity at a minimal cost.

c. Implement a demand-driven breeding program utilizing the Tricot approach (90, 91) that can be spearheaded by NARO, with crop-specialized ZARDIs assuming leadership roles across diverse agroecological zones to advance the

13 Tricot, short for "Triadic Comparison of Technology Options," is a citizen science approach that actively engages hundreds of farmers and consumers in evaluating crop varieties. This multidisciplinary, data-driven method utilizes the ClimMob platform to scale the evaluation of agricultural technologies in target environments by involving farmers and consumers in active participation and feedback. In contrast to traditional large-scale field trials, Tricot enables farmers to directly assess plant varieties in their fields under realistic conditions, considering diverse contexts.

development of improved varieties with traits resilient to environmental stresses, pests, and diseases and meet market demand and consumer preferences. The program should actively engage members of different farmer research groups, CSB groups, LSB groups, and out-growers collaborating with private seed companies interested in participating in on-farm experimentation and evaluating varieties. To facilitate this initiative, breeding lines sourced from public research institutions such as NARO, Universities, and CGIAR, along with characterized genebank materials, released improved varieties, and CSB materials with superior genotypes, can be utilized for participatory evaluation.

3. Adopt a program for continuous dialogue to improve seed-related policies, regulations, and directives.

The policy and strategy of the Ugandan seed system are forward-thinking, as they promote crop diversification and encourage various stakeholders' involvement in seed system development. However, as highlighted in our analysis in sections 3.2.1.1 and 3.2.3.1, several challenges persist. These include the absence of some key regulations, directives, and procedural guidelines and shortcomings in implementing existing rules and regulations. Furthermore, the lack of independent bodies, attributed to insufficient resources and capacities, hampers the performance of various seed system actors. Consequently, this situation not only hinders healthy competition and innovation but also impedes the delivery of high-quality new plant varieties and seeds tailored to the needs of Ugandan farmers. A dialogue to improve seed-related policies, regulations, and directives should consider the following:

a. Institute an annual or biannual seed governance dialogue forum, facilitating the exchange of information among network members and pertinent stakeholders regarding government policies, strategies, legal provisions, restrictions, and updates.

b. Identify central laws and regulations hindering variety development, seed production, and actors' seed distribution/marketing efforts. Initiate dialogues aimed at proposing changes and adopt a proactive approach to advocating for reform. This necessitates the active involvement of network members and representatives from farming communities in consultations and advocacy endeavors.

c. Implement the 2018 national seed policy in totality by revising the Seeds and Plant Variety Act in line with the policy prescriptions outlined in section 1.6.1 of the national seed policy and the Plant Variety Protection Act as outlined in section 1.6.2 of the national seed policy.

6 LIMITATIONS OF THE STUDY

This research is unique in that it is comprehensive, unlike many seed system literature on Uganda that focuses only on one or few aspects of the country's seed system development, such as policy and regulations, farmers' seed system, or the formal seed system. By covering all seed systems, actors, and their activities, strengths, weaknesses, and challenges that have shaped the current seed system functioning in Uganda and its outcome on the ground, i.e., available crop diversity and farmers' seed security that we have documented, we believe that this study provides rich information for a diverse set of actors.

That said, this study used 73 key informant interviews with local and national seed system actors, eight FGDs with 65 farmers in four districts — one male group and one female group per district, two national workshops, document analysis, and a roundtable meeting to validate the study. The qualitative data we gathered from these participants, documents, and meetings covering actors actively working nationwide and in the four study sites with varying degrees of commercial orientation representing different agro-ecologies and socio-economic conditions offered rich data. However, limitations that affect representativeness at a broader scale or national level are still unavoidable. Uganda is highly diverse in agro-ecology, and various crops with different means of propagation grow in these diverse agro-ecologies, which makes it difficult to say that the current crop diversity and seed security study in the four districts focusing on two key crops per site can provide the whole picture. For instance, we could not cover the very northern region of Uganda due to time and resource constraints. This might have added value to understanding seed system functioning and seed security situations in dryland areas, as the crops and farming systems differ.

Our conceptual framework combines actors, seed system function, and seed security frameworks as one of the pioneering approaches to studying all seed systems in a given place or for a given crop. The four-cell analysis is instrumental in capturing varietal diversity and suitability and mapping the trends in abundance and richness of the diversity. We understand the weakness of the 4-cell method that we used in assessing varietal suitability; one of the weaknesses is that the classification of the four cells into large or small areas is based on the perception of the farmers and will often vary from each geographical location based on agro-ecology and landholding of that area.

References

1. MAAIF, *National Seed Policy of Uganda* (Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), Entebbe, Uganda, 2018), pp. 22.
2. Parliament of Uganda (2006) Seeds and Plant Act 2007. (Uganda Gazette No. 32, Volume C, 29th June 2007, Entebbe, Uganda).
3. Parliament of Uganda (2014) The Plant Variety Protection Act. ed P. o. Uganda (Uganda Gazette 76, 24 December 2014, Entebbe, Uganda).
4. Parliament of Uganda (2020) Seeds and Plant (Quality Declared Seed) Regulations, 2020. ed P. o. Uganda (Uganda Gazette No. 6, Volume CXIII, 24th January 2020, Entebbe, Uganda).
5. COMESA, *COMESA Seed Trade Harmonisation Regulations* (Alliance for Commodity Trade in Eastern and Southern Africa (ACTESA), Specialised Agency of COMESA, Lusaka, Zambia, 2014).
6. MAAIF (2016) The seed and plant regulation. in *Uganda Gazette*, ed A. I. a. F. Ministry of Agriculture (Ministry of Agriculture, Animal Industry and Fisheries, Entebbe, Uganda), p 90.
7. F. Bagamba, P. R. Ntakyo, G. Otim, D. J. Spielman, B. Van Campenhout, Policy and performance in Uganda's seed sector: Opportunities and challenges. *Development Policy Review* **41**, e12665 (2023).
8. Parliament of Uganda (2005) The national environment (access to genetic resources and benefit sharing) regulations. (Ugaruln Gazette No. 15, Volume XCVIII, 18th March 2005, Entebbe, Uganda).
9. R. A. Walker, T. Stucka, F. Mikulcak, R. K. Sebudde, *Uganda Economic Update, 12th Edition : Developing the Agri-Food System for Inclusive Economic Growth*, Uganda Economic Update No. 12 (World Bank Group, Washington, D.C., 2018).
10. J. P. K. Kagorora, M. K. Kansiime, C. Owuor, J. Tumwine, *A review of some aspects of Uganda's crop agriculture: challenges and opportunities for diversified sector output and food security*, CABI Working Paper 26 (Wallingford, UK, CABI, 2021), pp. 22.
11. MAAIF, *National agricultural policy* (Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), Entebbe, Uganda, 2013).
12. D. N. Mubiru *et al.*, Climate trends, risks and coping strategies in smallholder farming systems in Uganda. *Climate Risk Management* **22**, 4-21 (2018).
13. CIAT, BFS/USAID, *Climate-Smart Agriculture in Uganda (CSA Country Profiles for Africa Series* (International Center for Tropical Agriculture (CIAT); Bureau for Food Security, United States Agency for International Development (BFS/ USAID), 2017).
14. MAAIF, *Uganda National Seed Strategy: 2014/15 – 2019/20* (Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), Entebbe, Uganda, 2015), pp. 113.
15. K. Kuhlmann, A. N. Nalinya, T. Francis, D. J. Spielman, *Mapping the design and implementation of seed sector regulation: The case of Uganda* (International Food Policy Research Institute, Washington D.C, USA, 2023), https://doi.org/10.2499/p15738coll2.136948.
16. E. Mabaya *et al.*, *Uganda Country Report 2022: The African Seed Access Index (version April 2023)*. N. Masereka, J. Jagwe, Eds. (2022).
17. P. P. Marenya *et al.* (2024) Plausible impact pathways for dryland crops: reaching the hard-to-reach. in *Workshop Report and Synthesis, 20 – 22 September 2023* (International Maize and Wheat Improvement Center (CIMMYT), Nairobi, Kenya.).
18. W. S. de Boef, H. Dempewolf, J. M. Byakweli, J. M. M. Engels, Integrating Genetic Resource Conservation and Sustainable Development into Strategies to Increase the Robustness of Seed Systems. *Journal of Sustainable Agriculture* **34**, 504-531 (2010).

19. C. J. M. Almekinders, N. P. Louwaars, *Farmers' seed production: new approaches and practices* (Intermediate Technology Publications, London, UK, 1999).

20. A. Christinck, F. Rattunde, W. Mulinge, E. Weltzien (2018) Identifying options for the development of sustainable seed systems: Insights from Kenya and Mali. in *ZEF Working Paper Series No. 165*, eds C. Borgemeister, J. v. Braun, M. Denich, T. Stellmacher, E. Youkhana (Center for Development Research (ZEF), Bonn).

21. S. Louafi *et al.*, Crop Diversity Management System Commons: Revisiting the Role of Genebanks in the Network of Crop Diversity Actors. *Agronomy* **11**, 1893 (2021).

22. J. van Etten, I. López Noriega, C. Fadda, E. Thomas, "The contribution of seed systems to crop and tree diversity in sustainable food systems" in Mainstreaming agrobiodiversity in sustainable food systems: Scientific foundations for an agrobiodiversity index, A. Bailey, Ed. (Bioversity International, Rome, 2017), pp. 80-101.

23. O. T. Westengen, S. P. Dalle, T. H. Mulesa, Navigating towards resilient and inclusive seed systems. *Proceedings of the National Academy of Sciences* **120**, e2218777120 (2023).

24. C. K. Khoury *et al.*, Crop genetic erosion: understanding and responding to loss of crop diversity. *New Phytologist* **233**, 84-118 (2021).

25. M. Halewood, "Farmers' crop varieties and farmers' rights: challenges in taxonomy and law", M. Halewood, D. Hunter, Eds. (Routledge, New York, 2016), pp. 1-24.

26. NMBU Seed System Lab (2023) Seed System Toolkit. (Norwegian University of Life Sciences (NMBU), Ås, Norway).

27. Seed System (2022) FGD Guidelines for "Community-Based Assessment"

28. B. Sthapit, P. Shrestha, M. Upadhyay, Eds., *On-farm management of agricultural biodiversity in Nepal: good practices* (NARC, LI-BIRD, and Bioversity International, Pokhara, Kaski, Nepa, 2012), Revised Edition Ed, p 74.

29. L. Mulugo, S. Ajambo, E. Kikulwe, *User guide to the four-square method for intervening in root, tuber and banana seed systems* (CGIAR Research Program on Roots, Tubers and Bananas (RTB), Lima (Peru), 2021).

30. A. Subedi, W. S. De Boef, G. Audet-Bélanger, P. Gildemacher, W. Heemskerk (2013) Seed systems analysis. ISSD Technical Notes Issue No 2. (Centre for Development Innovation, Wageningen UR & Royal Tropical Institute, Amsterdam), p 7.

31. TASAI (2022) The African Seed Access Index. (TASAI).

32. J. M. Chevalier, D. J. Buckles, "Module 6: Understanding Systems - System dynamics" in Handbook for Participatory Action Research, Planning and Evaluation. (SAS2 Dialogue, Ottawa, Canada, 2021), pp. 119-124.

33. J. M. Chevalier, D. J. Buckles, *Participatory action research: Theory and methods for engaged inquiry* (Routledge, 2019).

34. NMBU (2015) Ethical guidelines for NMBU. Adopted by the Board of the Norwegian University of Life Sciences on 26 November 2015. (NMBU, Ås, Norway), p 21.

35. Etikkom (2014) Research Ethics Checklist. (The Norwegian National Committees for Research Ethics, Oslo, Norway).

36. J. M. Powell, T. O. Williams, "An overview of mixed farming systems in sub-Saharan Africa" in International Conference on Livestock and Sustainable Nutrient Cycling in Mixed Farming Systems of Sub-Saharan Africa, Addis Ababa (Ethiopia), 22-26 Nov 1993, J. M. Powell, S. Fernández-Rivera, T. O. Williams, C. Renard, Eds. (International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia, 1995), pp. 27-43.

37. D. N. Mubiru, P. Kristjanson, *Summary of baseline household survey results: Hoima district, west central Uganda* (CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS), Copenhagen, Denmark., 2012).

38. J. S. Okonya, K. Syndikus, J. Kroschel, Farmers' perception of and coping strategies to climate change: Evidence from six agro-ecological zones of Uganda. *Journal of agricultural science* **5**, 252 (2013).

39. J. L. Dixon, L. C. Stringer, A. J. Challinor, Farming System Evolution and Adaptive Capacity: Insights for Adaptation Support. *Resources* **3**, 182-214 (2014).

40. B. A. Lukuyu *et al.*, *An assessment of livestock production systems and local feed resources used to inform feed utilisation and livestock production in the Mbarara District of Uganda* (International Livestock Research Institute (ILRI), Nairobi, Kenya, 2021), pp. 16.

41. R. A. T. Juarez, M. Tusiime, Characterising agricultural holdings in Uganda: Inputs to improving policy formulation. *Journal of Development and Agricultural Economics* **15**, 11-25 (2023).

42. Y. Haneishi *et al.*, Exploration of rainfed rice farming in Uganda based on a nationwide survey: Evolution, regionality, farmers and land. *African Journal of Agricultural Research* **8**, 3318-3329 (2013).

43. C. S. Wortmann, C. A. Eledu, *Uganda's agroecological zones : a guide for planners and policy marker* (International Center for Tropical Agriculture (CIAT), Cali, Colombia, 1999), pp. 54.

44. C. W. Whitney *et al.*, Crop diversity in homegardens of southwest Uganda and its importance for rural livelihoods. *Agriculture and Human Values* **35**, 399-424 (2018).

45. W. Tesfaye, N. Tirivayi, Crop diversity, household welfare and consumption smoothing under risk: Evidence from rural Uganda. *World Development* **125**, 104686 (2020).

46. G. Eilu, J. Obua, J. K. Tumuhairwe, C. Nkwine, Traditional farming and plant species diversity in agricultural landscapes of south-western Uganda. *Agriculture, Ecosystems & Environment* **99**, 125-134 (2003).

47. M. Coromaldi, G. Pallante, S. Savastano, Adoption of modern varieties, farmers' welfare and crop biodiversity: Evidence from Uganda. *Ecological Economics* **119**, 346-358 (2015).

48. L. Mulugo, P. Kibwika, F. B. Kyazze, A. O. Bonaventure, E. Kikulwe, The contestations of diversity, culture and commercialization: why tissue culture technology alone cannot solve the banana Xanthomonas wilt problem in central Uganda. *Agriculture and Human Values* **39**, 1141-1158 (2022).

49. P. J. van Asten *et al.*, *Coffee-Banana Intercropping: Implementation guidance for policymakers and investors*, Climate-Smart Agriculture Practice Brief (CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Copenhagen, Denmark, 2015), https://hdl.handle.net/10568/69017.

50. MAAIF and MWE, *National Irrigation Policy: Agricultural Transformation Through Irrigation Development* (Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) and Ministry of Water and Environment (MWE), Entebbe Uganda, 2017).

51. M. Thomas *et al.*, On-farm dynamic management of genetic diversity: the impact of seed diffusions and seed saving practices on a population-variety of bread wheat. *Evolutionary Applications* **5**, 779-795 (2012).

52. J. Enjalbert *et al.*, Dynamic management of crop diversity: From an experimental approach to on-farm conservation. *Comptes Rendus Biologies* **334**, 458-468 (2011).

53. B. De Jonge *et al.*, Advances in the Registration of Farmers' Varieties: Four Cases from the Global South. *Agronomy* **11**, 2282 (2021).

54. T. Recha *et al.* (2019) Report of the International Workshop on Registration of Farmers' Varieties, 4-7 December 2018. (Bioversity International and Oxfam Novib, Entebbe, Uganda).

55. Crop Trust, *Uganda Genebank Review Report*, An assessment supported by Biodiversity for Opportunities, Livelihoods and Development (BOLD) project's Work Package 1 on Capacity and resource development (Crop Trust, Bonn, Germany, 2022).

56. FAO, *Genebank Standards for Plant Genetic Resources for Food and Agriculture* (Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, ed. Revised edition, 2014), pp. 166.

57. Parliament of Uganda (2005) The National Agricultural Research Act. ed P. o. Uganda (Uganda Gazette 74, 21 November 2005, Entebbe, Uganda).

58. NARO, *NARO Variety Allocation List for certified seed production and marketing to licensed seed companies* (National Agricultural Organization (NARO), Entebbe, Uganda, 2023), pp. 1.

59. A. Bruno *et al.*, Participatory farmers' selection of common bean varieties (Phaseolus vulgaris L.) under different production constraints. *Plant Breeding* **137**, 283-289 (2018).

60. B. Kiiza, L. G. Kisembo, R. O. M. Mwanga, Participatory plant breeding and selection impact on adoption of improved sweetpotato varieties in Uganda. *Journal of Agricultural Science and Technology* (2012).

61. E. Mbeyagala *et al.*, Participatory selection of mungbean genotypes in Uganda. *African Crop Science Journal* **25**, 253-262 (2017).

62. C. M. Mukankusi *et al.*, *Participatory evaluation of common bean for drought and disease resilience traits in Uganda*, CCAFS Working Paper no. 143 (CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Copenhagen, Denmark, 2015), pp. 52.

63. R. O. Mwanga *et al.*, 'NASPOT 11', a sweetpotato cultivar bred by a participatory plant-breeding approach in Uganda. *HortScience* **46**, 317-321 (2011).

64. R. W. Gibson, E. Byamukama, I. Mpembe, J. Kayongo, R. O. M. Mwanga, Working with farmer groups in Uganda to develop new sweet potato cultivars: decentralisation and building on traditional approaches. *Euphytica* **159**, 217-228 (2008).

65. G. Otieno, M. Halewood, P. Bissessur, M. E. Dulloo, *Enhancing Access and Benefit Sharing related to Crop Wild Relatives in southern and eastern Africa, pp. 61, under* DI SADC CWR project report (Alliance of Bioversity and CIAT, Rome, Italy, 2022), pp. 61.

66. A. Mastenbroek, I. Sirutyte, R. Sparrow, Information Barriers to Adoption of Agricultural Technologies: Willingness to Pay for Certified Seed of an Open Pollinated Maize Variety in Northern Uganda. *Journal of Agricultural Economics* 10.1111/1477-9552.12395 (2020).

67. M. K. Kansiime, A. Mastenbroek, Enhancing resilience of farmer seed system to climate-induced stresses: Insights from a case study in West Nile region, Uganda. *Journal of Rural Studies* **47**, 220-230 (2016).

68. J. Joughin, *The political economy of seed reform in Uganda: promoting a regional seed trade market*, Africa trade practice working paper series No. 3 (World Bank, Washington, D.C., 2014), pp. 48.

69. R. Edema, A. Ozimati, I. Dramadri, Seed systems in Uganda: review of current status and future needs. *African Journal of Rural Development* **6**, 123-144 (2021).

70. C. Longley *et al.*, *Uganda seed sector profile: A Feed the Future Global Supporting Seed Systems for Development activity (S34D) report.*, A Feed the Future Global Supporting Seed Systems for Development activity (S34D) Report (Catholic Relief Services, Baltimore, USA, 2021), https://hdl.handle.net/10568/119639.

71. E. B. Rubaihayo *et al.*, Development of mechanisms for sustainable production and utilisation of indigenous vegetables and management of their genetic diversity in Uganda. *Unpublished report. Faculty of Agriculture, Makerere University Kampala* (2003).

72. M. Obura, G. Oballim, J. Ochuodho, F. Maina, V. Anjichi, Seed Management and Quality of Farmer Saved Seeds of Bambara groundnut from North Western, Northern and Eastern Uganda. *Ghana Journal of Agricultural Science* **56**, 1-15 (2021).

73. ISSD Uganda, *Integrated Seed Sector Development Plus project (ISSD Plus) Close Out Report* (ISSD Uganda, Kampala, 2021), pp. 53.

74. M. Waithaka, M. Mugoya, E. Mabaya, K. Tihanyi, *Decentralized Seed Services in Africa: An Assessment of Tanzania and Uganda*, Working Paper 206 (Center for Development Research, University of Bonn, Bonn, Germany, 2021).

75. E. Akpo *et al.*, Legume seed production for sustainable seed supply and crop productivity: case of groundnut in Tanzania and Uganda. *Journal of Crop Improvement* **34**, 518-539 (2020).

76. BMG and USAID, *Early Generation Seed Study* (Bill and Melinda Gates Foundation and USAID, 2015), pp. 122.

77. A. Mastenbroek, B. Ntare, *Uganda Early Generation Seed Study: Unlocking pathways for sustainable provision of EGS for food crops in Uganda*, Report CDI-16-030 (Wageningen University & Research (Wageningen UR) Centre for Development Innovation, Wageningen, the Netherlands, 2016).

78. C. Longley, O. Suji, C. Tindiwensi, J. Adriko, E. Walters, *Participatory Impact Assessment of World Vision Emergency Seed Intervention in Adjumani District, Northern Uganda*, A Feed the Future Global Supporting Seed Systems for Development activity (S34D) report (Catholic Relief Services, Baltimore, United States, 2023).

79. J. Donovan, R. C. Voss, I. Bayiyana, P. Rutsaert, Maize seed aid and seed systems development: Opportunities for synergies in Uganda. *Outlook on Agriculture* **0**, 00307270231224085 (2024).

80. ISSD Uganda, *Seed Tracking and Tracing System* (ISSD Uganda and Wageningen Centre for Development Innovation, Kampala, Uganda, 2020).

81. A. Mastenbroek, G. Otim, B. R. Ntare, Institutionalizing Quality Declared Seed in Uganda. *Agronomy* **11**, 1475 (2021).

82. Parliament of Uganda (2016) Plant Protection and Health Act. (Uganda Gazette 17, 11 March 2016, Entebbe, Uganda), p 15.

83. C. Musoke, F. B. Kyazze, P. Kibwika, S. Kyamanywa, S. Mukasa, The certified sweet potato seed system evolution process: A case of Omoro and Mpigi districts in Uganda. *African Journal of Food, Agriculture, Nutrition and Development* **24**, 25731-25748 (2024).

84. C. J. M. Almekinders *et al.*, Why interventions in the seed systems of roots, tubers and bananas crops do not reach their full potential. *Food Security* **11**, 23-42 (2019).

85. FAO, *Household seed security concepts and indicators. Discusion paper* (Food and Agriculture Organization of the United Nations and European Commission humanitarian aid department, Rome, 2015).

86. T. Hodgkin *et al.*, "Seed systems and crop genetic diversity in agroecosystems" in Managing biodiversity in agricultural ecosystems, D. I. Jarvis, C. Padoch, H. D. Cooper, Eds. (Columbia University Press, New York, US, 2007), pp. 77-116.

87. CGIAR, *Multi-stakeholder framework for intervening in RTB seed systems: user's guide*, RTB Working Paper No. 2016-1 (Consultative Group on International Agricultural Research (CGIAR) Program on Roots, Tubers and Bananas, Lima, 2016), http://dx.doi.org/10.4160/23096586RTBWP20161, pp. 13.

88. S. Ahmed, J. R. Stepp, Beyond yields: Climate change effects on specialty crop quality and agroecological management. *Elementa: Science of the Anthropocene* **4** (2016).

89. O. T. Westengen, K. Skarbø, T. H. Mulesa, T. Berg, Access to genes: linkages between genebanks and farmers' seed systems. *Food Security* **10**, 9-25 (2018).

90. J. v. Etten *et al.*, *The tricot citizen science approach applied to on-farm variety evaluation: methodological progress and perspectives*, RTB Working Paper. No. 2021-2 (CGIAR Research Program on Roots, Tubers and Bananas (RTB), Lima, Peru, 2020), https://doi.org/10.4160/23096586RTBWP20212.

91. J. Van Etten *et al.*, First experiences with a novel farmer citizen science approach: crowdsourcing participatory variety selection through on-farm triadic comparisons of technologies (TRICOT). *Experimental Agriculture* **55**, 275-296 (2016).