ANNEX 2

Uganda

Maize and Beans
Version 4

2024

RE-GAIN: Scaling Solutions for Food Loss in Africa

CONTENTS

LIST OF TABLES

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ACRONYMS

AFOLU	Agriculture, Forestry and Other Land Use
ARCAFIM	Africa Rural Climate Adaptation Finance Mechanism
AGI	Agro Industrialisation
AGRA	Alliance for a Green Revolution in Africa
APHLIS	African Post-Harvest Loss Information System
ARAF	Acumen Resilient Agriculture Fund
ARCAFIM	Africa Rural Climate Adaptation Finance Mechanism
BAU	Business as Usual
CASA	Commercial Agriculture for Smallholders and Agribusiness
CCA	Climate Change Adaptation
CERC	Contingency Emergency Response Unit
CMIP	Coupled Model Intercomparison Project
CSA	Climate Smart Agriculture
CLP	Critical Loss Point
EARF	Energy Access Relief Facility
ENSO	El Niño Southern Oscillation
ESS	Environment and Social Safeguards
EU	European Union
FAO	Food and Agriculture Organization
FOAG	Farmers Overseas Action Group
FL-RS	Food Loss Reduction Solutions
GCF	Green Climate Fund
GDP	Gross Domestic Product
GFDRR	Global Facility for Disaster Reduction and Recovery
GHG	Greenhouse Gas
GHGI	Greenhouse Gas Inventory
HDPE	High-density Polyethylene

ICRF	Infrastructure Climate Resilient Fund
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter Tropical Convergence Zone
LULC	Land Use and Land Cover
MSME	Micro, Small, and Medium Enterprises
NAADS	National Agricultural Advisory Services of Uganda
NAES	National Agricultural Extension Strategy
NAP	National Agriculture Policy
NCCCS	National Climate Change Communication Strategy
NDA	National Designated Authority
NFP	National Fertiliser Plan
NDC	Nationally Determined Contributions
NDP	National Development Plan
NGO	Non-Government Organisation
REPP	Renewable Energy Performance Platform
SDG	Sustainable Development Goals
SIL	Soybean Innovation Lab
SME	Small and Medium Enterprises
SSA	Sub-Saharan Africa
SSP	Socioeconomic Pathway
TIMPs	Technologies, innovations, and management practices
UCA	Uganda Cooperative Alliance
UGGDS	Uganda Green Growth Development Strategy
UGEAP	Universal Green Energy Access Programme
UN	United Nations
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WFP	World Food Programme

Executive Summary

Africa's food insecurity challenge has been exacerbated by climate change, with the FAO estimating that post-harvest losses in agriculture contribute to between 30% and 50% of the continent's total food loss (FAO, 2011)**.** Post-harvest food loss, which refers to the reduction in quantity and quality of crops once harvested, occurs during various stages, including handling, storage, processing, and transportation. The impacts of these losses include reduced food availability, economic losses for farmers, and increased food insecurity. Climate change exacerbates these issues with rising temperatures, erratic rainfall, and extreme weather events contributing to increased spoilage, pest infestations, and mould growth, further intensifying global food losses. In Uganda, maize and beans, two key crops, are significantly affected, with post-harvest losses reaching up to 13% for maize (APHLIS, n.d.) and 30-40% for beans (Commercial Agriculture for Smallholders and Agribusiness (CASA), 2020). These losses impact food security and economic stability in Uganda. The country's frequent floods, droughts, and erratic rainfall exacerbate these food losses, jeopardizing the livelihoods of over 72% of the population that relies on agriculture, and posing a serious threat to the nation's overall food security and economic well-being (Uganda Bureau of Statistics, 2022b).

Given the threat of climate change and the significance of agriculture to the economy, the management of post-harvest food losses within Uganda's agricultural activities and growing seasons, specifically maize and beans crop production, is necessary to ensure socio-economic stability. Agriculture is a crucial part of Uganda's economy, supporting the livelihoods of around 7 million households and contributing 24% to the GDP (The World Bank, n.d.) while employing approximately 72% of the workforce (Uganda Bureau of Statistics, 2022b). Smallholder farmers, primarily cultivate maize and beans, among other crops. Maize is essential to Uganda's food security and economy, largely used for human consumption and animal feed. Beans are equally important for Uganda, serving as a vital source of protein and nutrition, and are often intercropped with maize. The country's agricultural activities are concentrated in various regions, with distinct growing seasons: the first season from March to May, and the second season from June to August (Uganda Bureau of Statistics, 2022b). Consideration of climate change impacts and associated mitigation and adaptation measures on crop production, processing, and subsequent food loss is therefore necessary to ensure socio-economic stability.

National policies and programmatic interventions that attempt to support climate change adaptation and mitigation along with post-harvest food losses are limited and require an intensified effort to support food security. Existing policies include Uganda's Vision 2040 (adopted in 2007) and the National Climate Change Policy (2015). These policies are largely targeted at enhancing agricultural productivity, promoting sustainable practices, and increasing climate resilience. Other programs have been initiated, such as the Africa Rural Climate Adaptation Finance Mechanism (ARCAFIM) and the Acumen Resilient Agriculture Fund (ARAF) under the Green Climate Fund (GCF). However, considering the significance of these sectors and the impacts of climate change on post-harvest food losses, Uganda's adaptation and mitigation efforts are inadequate, underscoring the need for deepened efforts towards the implementation of climate-resilient practices and technologies.

A deeper understanding of the climate risks associated with Uganda's agricultural sector is necessary to determine appropriate climate adaptation measures. Uganda faces significant climate risks, including increased temperatures, erratic rainfall, prolonged droughts, and frequent floods. These risks predominantly affect the northern, eastern, and southwestern regions, with areas around Lake Victoria (African Development Bank and the University of Cape Town, 2019) and the Karamoja region being particularly vulnerable (The World Bank, 2021). The impacts of these climate risks include soil erosion, reduced agricultural productivity, water scarcity, and increased pest and disease outbreaks, leading to food insecurity and economic instability. Historically, Uganda has experienced a rise in average temperatures by 1.3°C since the 1960s and an

increase in extreme weather events (The World Bank, 2021). Climate change projections indicate that under the SSP2-4.5 and SSP5-8.5 scenarios, Uganda will continue to see rising temperatures, with average increases between 1.5°C and 3.0°C by 2040, along with more intense and unpredictable rainfall patterns (The World Bank, n.d.). These projected trends underscore the urgent need for comprehensive climate adaptation and mitigation strategies in Uganda.

The prevalence of these climate risks necessitates the application of adaptation measures to ensure the minimization of post-harvest food losses. For maize, increasing temperatures and erratic rainfall lead to reduced yields and increased post-harvest losses. This is evident with the trend of rising temperatures and more frequent droughts, particularly from the 1960s onwards. These climate trends have led to substantial impacts on yield, which have displayed a negative trend under a steadily warming environment (USDA, 2024). Projections indicate that maize yields will decrease further, with one study estimating that maize yields could decline by as much as 15.6% by 2050 in Uganda as a result of drought (Bwambale & Mourad, 2021). Additionally, post-harvest losses are exacerbated by higher temperatures and humidity, which promote pest infestations and mold growth. The losses will negatively affect food security and economic stability, as reduced yields will result in decreased income for farmers and higher food prices. Managing adaptation measures to stabilize maize yield and reduce post-harvest losses due to drought and variable rainfall is therefore critical for the value chain.

Beans are similarly impacted by climate change, with increased temperatures and unpredictable rainfall patterns leading to reduced yields and increased food losses during the drying and storage processes. For instance, the increased frequency of heavy rainfall events has resulted in higher moisture content in beans, leading to mold and spoilage during storage. The implication of these climate impacts on beans includes decreased food security and economic losses for farmers who rely on bean production for their livelihoods. Therefore, climate adaptation measures for the growing and processing of beans are vital to mitigate the negative effects of increased temperatures and erratic rainfall on production.

Like adaptation, mitigation efforts are needed to minimize the negative effects of climate change on Uganda's agricultural sector. Uganda has seen substantial changes in land use, with only 35% of its arable land currently under cultivation, despite 80% of the land being considered arable (United States of America - Department of Commerce, 2023).. The country has experienced a drastic loss of forest cover, with approximately 63% of its forests disappearing between 1990 and 2016, primarily due to agricultural expansion, deforestation, and urbanization. The conversion of grasslands and wetlands into agricultural land has also been a major driver of these changes, reflecting the pressures of population growth and the increasing demand for food production (Kuule D. A., et al., 2022)..

Additionally, Uganda's emissions trajectory is concerning, with agriculture and land use changes contributing to approximately 28 MtCO2e of the country's greenhouse gas emissions (Climate Watch, n.d.)**.** Uganda's GHG inventory projects a substantial increase in emissions by 2030 under business-as-usual (BAU) scenarios. Emissions from the Agriculture, Forestry and Other Land Use (AFOLU) sector are projected to increase between 2020 and 2030 under the BAU emissions scenario, reaching 122.2 $MtCO_2e$ by 2030 (Ministry of Water and Environment, 2022). Mitigation of these emissions is critical in the response to climate change.

Of Uganda's emissions contributions, food losses account for a significant proportion of emissions, particularly in the post-harvest value chain. The emissions associated with food loss across the agricultural value chains considered by the RE-GAIN programme for Uganda could amount to 825,994 tCO2e from maize and 8,734 tCO2e from beans, based on smallholder production values. Without intervention, emissions related to post-harvest losses on smallholder farms are expected to increase by between ~21% across the target countries For Uganda, this could amount to 681,750 tCO2e for maize and 7,216

tCO2e for beans by 2032. Therefore, it is crucial to minimize post-harvest food losses to reduce emissions and support climate change mitigation efforts.

The bulk of post-harvest losses contributing to agricultural emissions and requiring adaptation measures from field to market occur during the harvesting, drying, and storage processes and are exacerbated by climate change. On-farm post-harvest losses in the maize value chain of to 13% (APHLIS, n.d.) occur because of inadequate drying and storage facilities, leading to mold growth and pest infestations. For beans, on-farm post-harvest losses of 30-40% beans (Commercial Agriculture for Smallholders and Agribusiness (CASA), 2020) occur largely because of improper handling and storage, resulting in spoilage and contamination. Non-climate factors such as poor infrastructure, lack of access to modern technology, and limited financial resources also contribute to food losses in Uganda. Increased temperatures and erratic rainfall due to climate change worsen the already high post-harvest losses of maize and beans because of accelerated spoilage and increased pest populations, further threatening food security. Climate change exacerbates these issues, making mitigation and adaptation through post-harvest food loss management more salient.

With this in mind, an evaluation of proposed physical Food Loss-Reduction Solutions (FL-RS) was conducted to identify those with the highest potential to reduce post-harvest food losses and protect harvests against growing impacts from climate hazards. The analysis started on exploring which physical solutions could support mitigate the impacts of the exacerbating climate risks. From this initial analysis, stakeholder engagements in all seven countries provided critical nuances, including advantages, disadvantages, and barriers to use, particularly for smallholder farmers. The assessment facilitated the development of a shortlist of seven relevant physical FL-RS solutions tailored to meet specific country needs, guiding the final selection of solutions to be supported and disseminated by the RE-GAIN programme. Prioritization factors included environmental impact, farmers' awareness, frequency of use, potential to reduce food losses, availability, and scalability for job creation. Affordable solutions such as solar-powered small-scale mechanized solutions are prioritized. Combining hermetic storage solutions with moisture meters is crucial for preventing spoilage and aflatoxin development, particularly in maize and beans. The final shortlist of prioritized solutions for each country considers synergies and increased potential impact on food loss reduction. **Communal use solutions include mechanical multi-crop threshers and shellers, moisture meters, and communal storage structures, while individual use solutions include tarpaulins, metal and plastic silos, hermetic bags, and biological storage protectants and control agents.** Partnerships with agricultural service providers are recommended for implementing high-cost solutions, and awareness of proper use is essential for effectiveness

The proposed physical solutions will be complemented by a suite of non-physical solutions, utilising extension services such as awareness-raising and capacity-building activities to create an understanding of the importance of reducing food losses and the competencies to properly implement the FL-RS solutions and generate demand. Access to physical solutions in itself is not enough to strengthen smallholder farmer's resilience to climate – there is a need to build knowledge within the communities as one of the key barriers to adoption of these solutions. Several extension activities are planned, including raising awareness among smallholder farmers about critical issues such as food losses, moisture content, aflatoxin contamination, pests, and proper storage methods, as well as environmental and safety aspects. Farmers will also learn about accessing finance, farm business management, climate change impacts, and crosscutting themes such as gender and youth. Training and capacity building will be organized through the network of village-based advisors (VBAs), leveraging AGRA's expertise and previous activities in this area, while also working in training lead farmers to become VBAs to ensure sustainability of the programme and broad knowledge dissemination. The training will cover various aspects of the agricultural process, including harvesting timing, use of weather forecast data, harvesting methods, operation and maintenance of machinery, and the proper use and maintenance of FL-RS such as moisture meters, drying methods, hermetic bags, and

silos. For traders and processors, the focus will be on transport logistics, packaging, adherence to quality standards, and value addition through whole grain processing and marketing strategies to enhance profitability and sustainability.

Critical to this is the development of innovative financing mechanisms, as there is a challenge with in both the supply and demand of FL-RS due to limited access to finance. The RE-GAIN Programme is strategically designed to reduce the cost and risk associated with the adoption and implementation of food-loss reduction solutions (FL-RS) by smallholder farmers and agricultural MSMEs across its target countries. The proposed financing mechanisms are tailored to the needs of smallholder farmers to improve both access and affordability by relieving farmers of the need to securitize loans, mitigating the burden of high interest rates, and facilitating access to necessary capital. The programme employs a multifaceted approach, combining catalytic grants and financial models to make FL-RS more affordable and accessible. For smallholder farmers, the programme introduces catalytic disbursements to lower the cost of essential technologies like hermetic bags, drying sheets, and storage solutions. These grants are strategically deposited in escrow accounts, ensuring that funds are released only upon successful distribution of FL-RS to farmers, thereby enhancing production and driving demand. For agricultural MSMEs, the programme facilitates the development and pilot testing of financial products tailored specifically for the purchase of FL-RS. These solutions include de-risking mechanisms and shared-risk models that encourage investment in more expensive FL-RS, such as threshers, moisture meters, and communal storage structures. The catalytic grants provided to MSMEs not only enhance their access to finance but also help build their credit track records, improve their bankability, and reduce the cost of loans. This approach strengthens the business case for FL-RS service provision, thereby expanding the market and making these solutions more widely available.

To ensure the positive effects created by the RE-GAIN are sustainable, the programme will support the revision of policies to enable FL-RS investments, including tax exemptions, certification and standards for FL-RS quality, and promote successful FL-RS business models for scaling up and replication. Active involvement and support from government organizations, both central and local, will be crucial. The programme will align with other projects and programmes to leverage synergies, utilize existing laws and policies on food loss reduction, MSME promotion, and smallholder support, and ensure effective and efficient programme management, including rigorous monitoring and incorporating lessons learned. Effective stakeholder engagement is essential and will involve raising awareness, providing programme information, and ensuring inclusivity for women, youth, minority groups, and all value chain actors. A grievance mechanism will also be put in place. Additionally, ensuring the availability of quality FL-RS and access to finance is vital to support long-term continuation.

This feasibility study showcases how climate change is likely to exacerbate food losses, and addressing post-harvest food losses in Uganda's maize and beans value chains is critical to enhancing food security, economic stability, and climate resilience in the country. The RE-GAIN Programme's comprehensive approach, combining physical and non-physical solutions with innovative financing mechanisms and policy support, is designed to mitigate climate impacts, reduce food losses, and provide extensive support to smallholder farmers. By prioritizing scalable, affordable technologies and strengthening community knowledge and access to finance, the programme aims to build sustainable agricultural practices that not only protect harvests but also contribute to the long-term socio-economic stability of Uganda. Successful implementation will require continued stakeholder collaboration, government support, and a focus on inclusivity to ensure that the benefits reach all segments of the agricultural sector.

1 Introduction

1.1 PROGRAMME BACKGROUND

A great deal of attention has been paid in recent decades to the impacts of climate change on crop production, i.e., on growing risks to agricultural productivity. Scholarly investigations and public and private research have invested heavily in identifying and – where feasible – quantifying the ramifications of climate change on crop yields, yield stability over seasons, and in exploring plausible management options for the emerging challenges (CGIAR, 2023). As governments and societies look at how to minimize the risks of climate change, the impact of these changes on food production is increasing, fuelling concerns about food security and livelihoods for current and future generations.

Food security, however, is affected not only by changes in crop production but by changes occurring throughout the crop value chain, including during post-harvest phases (Akoth, 2020)**.** It is therefore crucial to examine the impacts of climate change on a crop's value chain, including production, aggregation, storage, transportation, processing, and distribution. Each stage comprises several sub-processes, and climate change may plausibly affect many or all of the sub-processes too.

With the lion's share of research and resources for resilience interventions in the agricultural sector having been focused on production, the RE-GAIN project is an effort to give dedicated focus to harvest and post-harvest stages of the value chain – specifically, harvesting, post-harvesting handling and storage, processing, transportation, and logistics. As summarized in Table 1-1, the International Fund for Agricultural Development (IFAD) report highlights a range of climate change concerns in the post-production stages of value chains and potential adaptation interventions that could increase resilience against such climate change concerns (IFAD, 2015).

Table 1-1 - Illustrative climate change risks and climate change risk management interventions in post-production value chain processes (adapted from IFAD, 2015)

Value Chain Components	Climate Risk Issues	Risk Management Interventions
Post-harvest management	Rising losses in harvest volume; declining safety, market quality and nutritional value due to increasing temperatures, humidity, pests and diseases.	Improve knowledge sharing on harvesting techniques to reduce losses. incentivize waste reduction measures and value addition for by-products; provide renewable energy sources to cover changing requirements for cooling, drying, milling, and threshing.
Siting of processing facilities	Extreme climate events (such as, floods, heatwaves, and storms) may damage processing facilities; shifting climatic conditions may render some sites redundant or increase transportation costs. It could create sustainable environment to pests and diseases, affecting both product quality and its suitability for consumption	Use hazard exposure and crop suitability maps to inform the siting of processing facilities; retrofit processing facilities with protective features; insure processing facilities against extreme climate events.
Energy in processing	High dependence on local bioenergy (wood, charcoal, dung, crop residues) has trade-offs with better soil management; rising temperatures require more energy for cooling.	Provide renewable energy sources (such as solar photovoltaic panels for cooling/drying/milling/heating, wind, biogas); equip processing facilities with energy-saving appliances (e.g., solar lighting, solar charging, efficient cook stoves); adopt pollution control measures.
Water in processing	Declining and more irregular water supplies; growing competition with other domestic or industrial users.	Re-site facilities closer to more suitable water sources; increase water storage and distribution capacity (water harvesting, communal ponds, groundwater recharge); introduce demand-side

Value Chain Components	Climate Risk Issues	Risk Management Interventions
		water efficiency measures; support conflict resolution for different water users (e.g., water user groups).
Packaging materials and methods	Rising temperatures and humidity may increase or decrease post-harvest losses and waste, as well as impact food safety, particularly if current packaging materials are impacted by high temperatures leading to produce damage or poor quality.	Design suitable packaging materials in parallel with waste and storage management strategies.
Processing infrastructure	Buildings and roads are exposed to higher peak rainfall, winds, and heat stress.	Introduce protective features and reinforcements into the design of critical infrastructure to handle run-off and higher temperatures; improve ventilation in buildings; harvest surplus water and energy from rooftops and appliances; use early warning systems.
Transport hubs and routes	Routes may become seasonally or permanently impassable (or open up); extreme events will disrupt logistics.	Re-site hubs; develop contingency plans for road, rail, water, and air transport; co-design value addition, storage, and transport components to avoid high-risk transport routes and seasons; upgrade docks, jetties, roads, and railways.
Refrigeration and cold chains	Temperature rises increase requirements for and costs of refrigeration; rising energy requirements increase greenhouse gas emissions.	Conduct cost-benefit analyses of dependency on refrigerated cold chains to assess best routes; introduce renewable energy sources for cooling and ventilation; optimize storage and transport management.
Just-in-time logistics	Extreme climate events (floods, storms, heatwaves) can make it impossible to comply with "just-in time" requirements.	Develop contingency plans for climate shocks and extreme events; create contingency storage opportunities; link into regional markets to avoid over-dependence on high-value export markets.
Demand from retail and consumers	Shifts in quantity and quality requirements and seasonality with climatic trends; disruptions in demand with climate variability, hence higher price fluctuations.	Assess market risks and opportunities before value chain implementation, including likely climatic impacts on high-value markets; strengthen and diversify storage to buffer price fluctuations; diversify into "off- season" crops.
Commodity labelling and certification	Increased consumer awareness as climate change may create new markets for sustainably produced and processed commodities with a low carbon footprint.	Explore opportunities for sustainable procurement, green labelling, and certification.

AGRA is a continental institution working in 15 African countries addressing food systems focussing on smallholder farmers' production, marketing and nutrition. In the countries where AGRA operates, which are highly diverse in terms of climate, soils, crop choices and institutional capacity, neither all of these climate-related concerns may be applicable, nor all of these potential interventions possible. **Even within the range of what may be applicable, this programme is likely to look at a subset of risks that may be viable to address, and – given resource constraints – only a limited number of high-priority resilience interventions may be feasible to design and deploy.** RE-GAIN is an effort to identify the most salient risks, select the most impactful solutions, and implement the priority interventions through a well-structured, strategic, multi-country programme.

1.2 BRIEF PROGRAMME DESCRIPTION

There is a clear gap in knowledge, data and interventions designed to target the impacts of climate change at the harvest and post-harvest stages of the value chain, despite the mounting evidence of the ramifications on food loss and the impact this has on land use changes and associated climate change mitigation. The majority of the current programmes designed to tackle climate-induced food loss focus on the pre-harvest stages of the value chain.

To address the pressing need for broader implementation of solutions aimed at reducing climate-related harvest and post-harvest food loss, the proposed programme is designed to raise awareness and build capacity to promote the adoption of Food Loss Reduction Solutions (FL-RS). It will do this by creating institutional capacity, facilitating the uptake of FL-RS by end users and service providers, increasing options of solutions' availability, and enabling practical application through policy interventions. This will include enhanced financial access for farmers and Micro, Small, and Medium Enterprises (MSMEs), empowering them to invest in climate-friendly FL-RS and incentivising vendors, manufacturers, and suppliers of climate-adapted FL-RS, fostering a robust market ecosystem.

A key focus is on strengthening the capabilities of countries to develop climate-resilient post-harvest infrastructure, both through providing physical solutions alongside capacity building along the value chains. This includes investing in strategic frameworks and implementation plans, including a regulated quality-based pricing system and tax exemptions on imports, for reducing food loss. By enhancing access to markets, the programme will encourage farmers to adopt FL-RS products and services, thereby boosting their climate and economic resilience.

1.2.1 Target Countries Overview

During the 2023–2027 period, AGRA plans to target 28 million farmers across 15 Sub-Saharan African countries, 40% of which will be women. The RE-GAIN Programme focuses on AGRA's activities in seven target countries, as shown in Figure 1-1 below. The RE-GAIN Programme is designed to combat food loss during the post-harvest stages and to boost climate resilience by fostering awareness and by building capacity for the adoption of Food Loss Reduction solutions (FL-RS). The programme aims to transfer these solutions to end users and service providers for practical application while facilitating financial access to farmers and Micro, Small, and Medium Enterprises (MSMEs) to invest in climate-resilient FL-RS. The programme plans to incentivize vendors, manufacturers, and suppliers to adopt these solutions and enhance the capacity of countries to develop climate-resilient post-harvest food handling infrastructure.

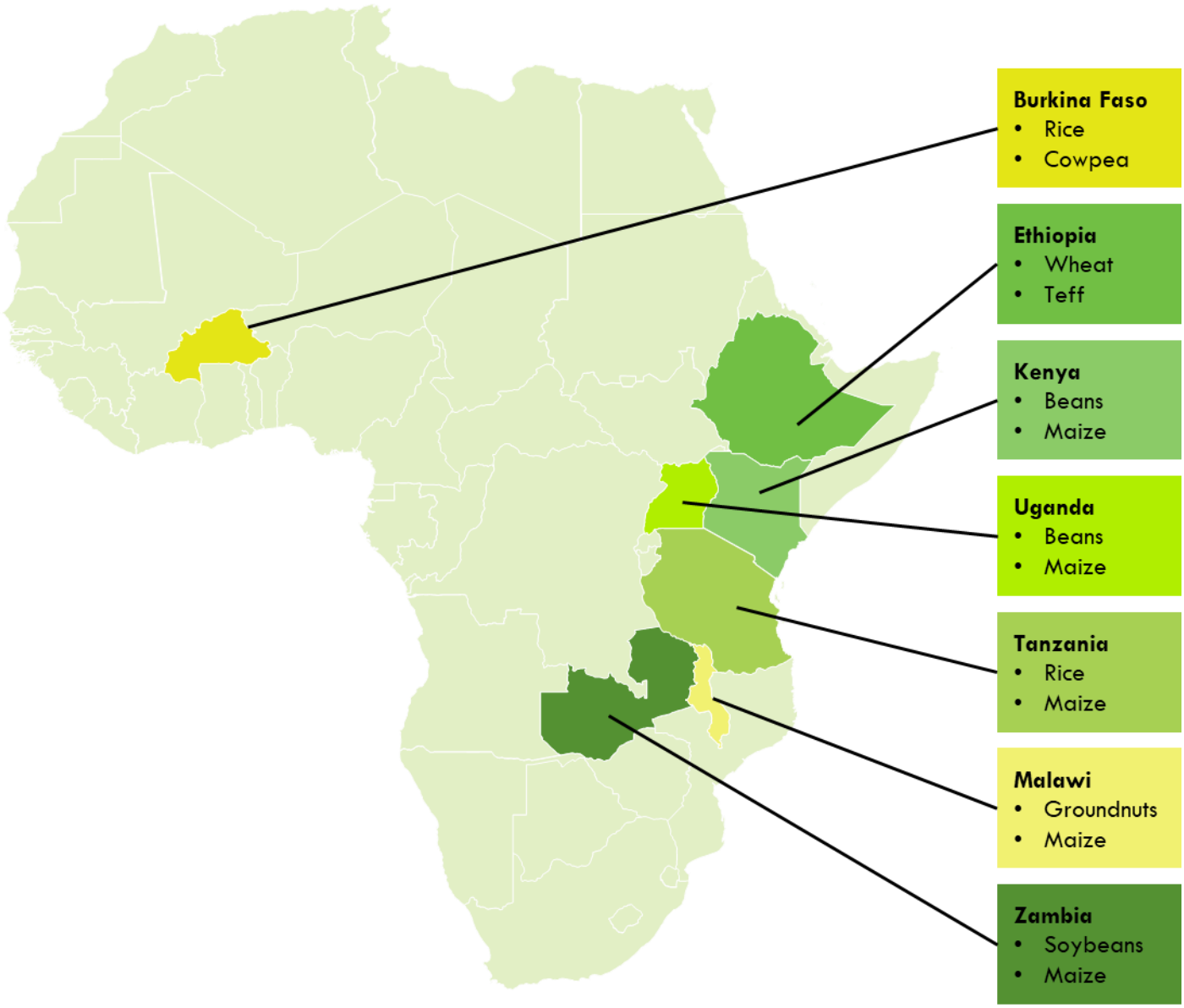


Figure 1-1 Focus Geographies for AGRA (2023-2027)

1.2.2 Crop selection

Key crops were identified by major stakeholders in the respective countries and expert assessments, supported by AGRA and the National Designated Authority (NDA) of each target country. Two major crops per target country were selected, based on area coverage, importance for food security and income, and climate vulnerability, to ensure that sufficient resources would be available for the crafting and execution of targeted solutions. Selected crops are representative of the agricultural dynamics of each country and aligned with the specific needs and strategic agricultural goals of the nation. In addition, these crops hold substantial importance to the country's food security and/or experience particularly high rates of loss within the value chain. Finally, these crops are produced in large parts of the respective countries by a significant number of smallholder farmers. The key crops, therefore, reflect the agronomic and economic realities of each country and provide opportunities for targeted enhancement of food security and sustainable agricultural practices. Additionally, the improved management of these crops is also expected to significantly reduction of GHG emissions contributing to the NDC targets of the countries involved. Figure 1-2 highlights the key crops selected for each of the countries within the programme.

1.2.3 Harvesting and Post Harvesting Definition

For the RE-GAIN programme, the key value chain stages considered are shown in Figure 1-2.

Figure 1-2 Strategic value chain stages included in the RE-GAIN Programme

The harvesting process within this RE-GAIN Programme proposal is defined as the interval between the culmination of agricultural production, marked by the crop reaching its maturity, and the initiation of post-harvest treatment. This process encompasses the identification of the optimal harvesting time and is further delineated into four distinct stages:

1. Removal of contaminated seeds, heads or cobs of matured crops at harvest
2. Reaping, which involves cutting, pulling, or gathering the mature crops.
3. Threshing, the process of separating the grain from the rest of the plant.
4. Cleaning, such as winnowing, to remove chaff and other impurities.
5. Hauling, which entails the transportation of the harvested produce to storage or processing facilities.

The post-harvest handling and storage stage commences once the crop exits the field and is typically conducted on the farm[1]. This stage encompasses several key operations, including:

1. Threshing, which can be performed manually or with mechanical threshing machines.
2. Drying, utilizing cribs, tarpaulins, and similar methods.
3. Cleaning and sorting, such as through winnowing, to remove impurities.
4. On-farm storage, which includes the use of granaries, hermetic bags, ordinary bags, stacks, metal silos, and plastic silos.
5. In some instances, primary processing activities, such as grinding, hulling, pounding, milling, drying, and sieving, are also conducted during this stage.

The processing, transportation, and logistics stage involves farmers selling their harvested crops either directly to traders, who collect the produce from the farm, or to collection centres and processors. These market participants then undertake the tasks of product accumulation, initial processing, quality control, grading, packaging, and transportation to wholesale buyers.

[1] In this instance, a field is where the crops are grown, and a farm consists of the whole small holding including the small aggregation site.

1.3 REASONING FOR REQUESTED FUNDING

Africa's food insecurity challenge has been exacerbated by climate change. Sub-Saharan Africa stands at a crossroads with an unprecedented opportunity for food systems transformation, driven by the demands of a rapidly growing population of 1.5 billion and the pressures of a changing climate (World Bank, 2023) (Worldometer, n.d.). The continent faces significant development challenges including food insecurity, resource degradation, poverty, gender inequality, and social exclusion. The vicious cycle of poverty and environmental degradation in Africa is evident in low crop productivity, deforestation, land degradation, conflict, migration, and vulnerability to climate shocks, which perpetuate persistent food insecurity and poverty. The effects of climate change are expected to be severe in Africa, where the capacity to adapt and respond to a changing climate is weak.

The impacts of climate change have increased over the past decades in Africa, manifesting in more frequent, intense, and prolonged extreme weather events, such as floods, droughts, heatwaves, locust outbreaks, desertification, and sandstorms. These extreme weather events have resulted in increased temperatures and humidity, shifts in precipitation patterns, water stress, and soil erosion. Most African countries already face recurrent droughts that affect growing seasons, often leading to short growing periods reducing the viability of farming in marginal agricultural areas. Projected reductions in crop yields in some countries could reach as much as 50% by 2030, and crop net revenues may fall by up to 90% by 2100, with smallholder farmers being the most affected (IPCC, 2018).

Therefore, the RE-GAIN programme aims to enhance the climate resilience and adaptive capacity of smallholders by promoting the widespread adoption of FL-RS in seven African countries. According to the World Bank estimates, a one percent reduction in post-harvest losses in Sub-Saharan Africa could lead to economic gains of $40 million each year, and most of the benefits would go directly to smallholder farmers (World Bank, 2011). Moreover, food loss and waste are the result of an extremely inefficient use of resources and account for about 3.3 gigatonnes of greenhouse gas emissions globally (FAO, 2013). Large amounts of water and fertilizer also go into the production of food that never reaches human mouths. Recovering the food that is lost during harvest and post-harvest handling some can help close that calorie gap in Africa while strengthening livelihoods and improving food security— without imposing any additional environmental cost. Therefore, facilitated by the Green Climate Fund (GCF) investment, RE-GAIN will roll out a suite of physical interventions alongside capacity building and enhanced financial and market access. Not only will this benefit the respective countries as whole, but it also has the potential to benefit the region and the wider planet.

1.4 PROGRAMME GOAL STATEMENT

IF the capacity of the target countries and communities to respond to climate-triggered food losses is strengthened through improved and inclusive access to financing, promotion of context-specific and gender-responsive innovations to reduce food losses, and better enabling conditions for public and private investments, **THEN** smallholder farmers will have enhanced food security and livelihood resilience, **BECAUSE** the widespread use of food loss-reduction technologies will reduce food loss and reduce the carbon footprint of food systems, while increasing household income and building the resilience of smallholder farmers, MSMEs and rural communities to climate shocks.

1.5 PURPOSE AND STRUCTURE OF THE REPORT

The purpose of this report is to provide an assessment of the climate hazards and vulnerabilities affecting each country and the distinct challenges they pose for the selected crops, and to propose a set of solutions designed to address these concerns.

The analysis considers the country contexts, alongside the appropriateness of the solutions from an environmental, social, and financial perspective.

The report begins with an overview of the country context, covering key land use trends and the regulatory landscape. This is followed by an in-depth climate analysis covering adaptation and mitigation measures, before looking at the potential solutions and proposed prioritisation, as well as the current state of the market for these solutions. Each of these country-specific reports concludes indicating the connection between the current climate risks and potential areas for mitigation activities within the selected value chain and the proposed solutions indicated. These in-depth country analyses are then summarized in Annex 2 Summary Feasibility Study which highlights the overarching narrative of the RE-GAIN Programme.

2 Country Context

2.1 SITUATION ASSESSMENT

Agriculture plays a crucial role in Uganda's economy, as highlighted by the Uganda Bureau of Statistics (2022b) and the United States Department of Commerce (2023). During the fiscal year 2022/23, the agricultural sector was responsible for about 24% of the country's GDP and contributed 35% to its export earnings (United States of America - Department of Commerce, 2023).

Agriculture employs around 72% of Uganda's workforce, with about 7 million households (80% of all households) engaged in farming or livestock rearing. For many of these households, agriculture remains the primary economic activity. This is particularly true for female-headed households, where 87% were engaged in agriculture in 2019, compared to 73% of male-headed households (Uganda Bureau of Statistics, 2022b). However, female-headed households only make up 23% of all agricultural households (Uganda Bureau of Statistics, 2022b). Women, despite being a significant part of the smallholder farming community, face challenges such as limited access to land, credit, and agricultural inputs, which affects their productivity and economic empowerment.

Crop production is the predominant agricultural activity in Uganda, with over 99% of agricultural households involved (Uganda Bureau of Statistics, 2022a). Most crops are grown for personal consumption, with 14.4% of households cultivating solely for their use and another 68% primarily for their use with some sales (Uganda Bureau of Statistics, 2022a).

The majority of agricultural workers are self-employed smallholders with landholdings of less than 2 hectares (Uganda Bureau of Statistics, 2022b)**.** The average holding size of agricultural households in Uganda is 1.24 hectares (Uganda Bureau of Statistics, 2022b). However, 66.5% of agricultural households have holdings of less than 1 hectare, and only 13.2% have more than 2 hectares (Uganda Bureau of Statistics, 2022b). Smallholder farmers often lack access to modern agricultural technologies and machinery, limiting their productivity. Most farming is manual, with available machinery primarily used for post-harvest processing rather than cultivation (Uganda Bureau of Statistics, 2022a).

Uganda's agriculture is dominated by several key staple crops essential for food security and the economy. Maize, bananas (especially matoke), cassava, beans, sweet potatoes, sorghum, millet, and groundnuts are the primary staples grown across various regions of the country (Uganda Bureau of Statistics, 2022b). Maize is a fundamental crop, widely cultivated for both human consumption and animal feed. Beans serve as a vital protein source and are often intercropped with maize. Sorghum and millet are traditional crops important in the diets of people in drier and northern regions. Groundnuts are also a common staple, used in various dishes and as a source of oil and protein. Overall, maize, beans and cassava, are the most cultivated crops: more than 50 percent of the agricultural households involved in their cultivation during 2019 (Uganda Bureau of Statistics, 2022b).

Post-harvest losses in Uganda are significant, with up to 30% of some crops lost between harvest and consumption. For instance, maize losses can reach to 13% (APHLIS, n.d.), and losses for fruits and vegetables can be as high as 40-50% (Kalita, 2017). The main causes of post-harvest losses include inadequate storage, transportation, processing and handling challenges. Many smallholder farmers lack access to proper storage facilities, leading to significant losses due to pests, rodents, mould, and spoilage. Traditional storage methods, such as open-air drying and poorly constructed granaries, are

often ineffective in preserving crops. Poor infrastructure and transportation challenges mean that crops often spoil before reaching markets. Inadequate road networks and lack of refrigerated transport exacerbate this problem. Limited access to modern processing facilities means that a significant portion of produce is lost during handling and processing. Manual processing methods can lead to contamination and physical damage to the produce.

The commercialization of Uganda's agricultural sector has tremendous potential, but there are areas that need improvement to fully unlock this potential. Enhancing the use of fertilizers and quality seeds, along with developing irrigation infrastructure, could significantly boost production and resilience against climatic extremes and pest infestations.

Advancing sector growth can be achieved by improving packaging capabilities, increasing storage facilities, and adopting better post-harvest handling practices. Additionally, expanding access to agricultural credit, reducing freight costs, and developing all-weather feeder roads in rural areas will facilitate smoother operations and market access. Simplifying the land tenure system and promoting modern production practices will also contribute to a more efficient and productive agricultural sector. With these improvements, Uganda's agriculture can thrive, ensuring food security and economic prosperity for its farmers.

Uganda faces the impacts of climate change, including increased temperatures, frequent disease outbreaks and insect infestations, disrupted rainfall patterns, and frequent floods and droughts (FAO, 2024). With 81% of the population engaged in rain-fed subsistence farming for food and cash income, the country's reliance on rain-fed agriculture poses a risk to economic growth, farmer incomes, and export earnings. The agriculture sector contributes to 27% of greenhouse gas (GHG) emissions, followed by the land-use and forestry sectors, which account for approximately 60% of emissions.

2.2 TRENDS OF LAND USE CHANGE

Uganda spans approximately 241,550.7 km², comprising 200 523.5 km² of land and 41,027.4 km² of open water and swamps. The country shares borders with Kenya to the east, Tanzania and Rwanda to the south, the Democratic Republic of Congo to the west, and South Sudan to the north. Agriculture is the primary source of livelihood for many Ugandans, with cropland being the most prevalent land cover, followed by grasslands, open water, forests, bushlands, wetlands, and built-up areas. Land use and cover types are significantly influenced by rainfall patterns (Mwanjalolo, et al., 2018).

Agriculture is one of Uganda's key growth sectors aimed at achieving socio-economic transformation and middle-income status by 2040 (M. B. Byaruhanga, 2024). In terms of land use, only 35% of Uganda's arable land is currently being cultivated, although about 80% of the country's land is considered arable (United States of America - Department of Commerce, 2023). This indicates a significant potential for further agricultural development if proper management practices and infrastructure improvements are implemented.

Over the past decade, Uganda has experienced significant changes in land use and land cover (LULC), driven primarily by agricultural expansion, deforestation, and urbanization. The most notable change is the increase in farmland. By 2021, farmland covered 35.8% of Uganda's total land area, up significantly from 7.2% in 1985. This expansion is mainly attributed to the conversion of grasslands and wetlands into agricultural land, driven by population growth and the increasing need for food production (Kuule D. A., et al., 2022).

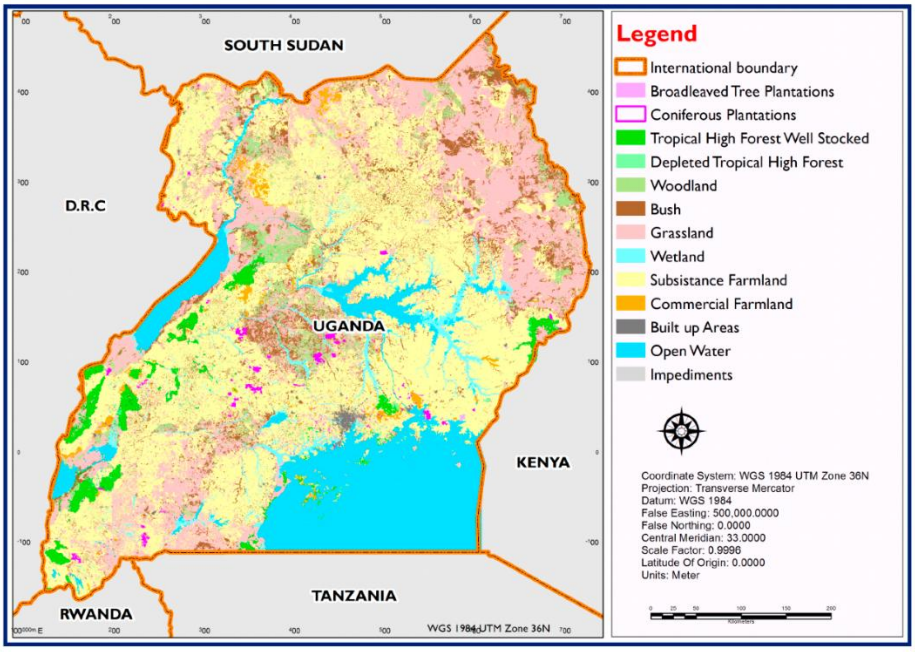


Figure 2-1 - Land use/cover for Uganda for the year 2015 (Mwanjalolo, et al., 2018)

Deforestation has also been a significant issue, with forested areas shrinking due to logging, agriculture, and settlement expansion. From 1990 to 2016, according to the (Ministry of Water and Environment, Republic of Uganda, 2016), Uganda lost approximately 63% of its forest cover, reducing from 4.9 million hectares to around 1.8 million hectares. Woodland areas have been particularly affected, being converted into farmland and urban spaces. For example, between 2005 and 2015, Uganda lost about 15% of its forest cover due to agricultural expansion and illegal logging. This reduction in forest cover is alarming because of its negative impacts on biodiversity, climate regulation, and ecosystem services. Forest degradation is also closely linked to the increased demand for wood fuel, which accounts for about 90% of Uganda's energy needs.

Urbanization has further contributed to the reduction of natural habitats. Rapid urban growth has led to the conversion of peri-urban and rural lands into residential, commercial, and industrial areas. This urban sprawl has further encroached on wetlands and grasslands, exacerbating environmental degradation (Kuule D. , et al., 2022).

Wetland areas have seen a notable decrease due to reclamation for agriculture and urban development. Grassland cover, which was 31.7% in 1985, dropped to 18.5% by 2021. These changes are largely driven by the pressures of agricultural development and population growth. Wetlands, which play crucial roles in water purification and flood regulation, have thus been significantly reduced (Mwanjalolo, et al., 2018).

The environmental impact of these LULC changes has been substantial. Issues such as soil erosion, reduced water quality, and increased greenhouse gas emissions have become more pronounced. In particular, agricultural practices in catchment areas have adversely affected water bodies, leading to nutrient loading and water quality degradation. The decline in water quality has been linked to intensive agricultural activities and deforestation, which increase sediment and nutrient runoff into water bodies.

2.3 NATIONAL AND SECTORAL POLICY LANDSCAPE

In Uganda, Government has adopted several long-term and mid-term development strategies, that also refer to the post-harvest food losses and the strategic approaches to address them, including:

Uganda Vision 2040 (adopted in 2007) (President of the Republic of Uganda, 2007) **lays out the general development objectives for Uganda over a 30-year period**. Its goal is to transform Uganda from a predominantly peasant and low-income country to a competitive upper middle income status country. It prioritizes agricultural development, and specifically in terms of reducing post-harvest losses, it aims to expand the network of market infrastructure including appropriate structures.

Uganda Green Growth Development Strategy (UGGDS 2017/18 – 2030/31) (National Planning Authority, 2017) **aims to ensure that the goals of the Uganda Vision 2040 and the NDPII 2015/16-2019/20 are attained in a sustainable manner**. The UGGDS focuses on five core investment areas of agriculture, natural capital management, green cities (urban development), transport and energy. The envisaged outcomes of the UGGDS implementation are income and livelihoods enhancement; decent green jobs; climate change adaptation and mitigation; sustainable environment and natural resources management; food and nutrition security; resource use efficiency; and social inclusiveness and economic transformation at the sub-national and national levels. The UGGDS seeks to accelerate economic growth and raise per capita income through targeted investments in priority sectors with the highest green growth multiplier effects; achieve inclusive economic growth along with poverty reduction, improved human welfare and employment creation; and ensure that the social and economic transition is achieved through a low carbon development pathway that safeguards the integrity of the environment and natural resources. '

Uganda Green Growth Development Strategy - Implementation Roadmap (UGGDS 2017/18 – 2030/31) (National Planning Authority, 2017) **sequences interventions for the short, medium and long term.** Achieving the National Green Growth Roadmap will hinge on the pursuit of the following broad strategic objectives:

- Accelerate inclusive, resilient and sustainable economic growth through restoration and valuation of natural capital and ecosystem services;
- Build and enhance sustainable infrastructure and green cities to harness existing economic, environmental and social opportunities;
- Strengthen climate change resilience, restoration and protection of ecosystems and their services for current and future generations;
- Harness balanced development opportunities that contribute to poverty reduction, creation of green decent jobs and equity in access to socioeconomic services by all.

Uganda's Third National Development Plan (NDPIII 2020-2025) (Ministry of Health of Uganda, 2020) **emphasizes the reduction of post-harvest losses and waste as a key component of increasing agricultural productivity and achieving food security**. The *Plan* defines the broad direction for the country and sets key objectives, interventions and targets for sustainable socioeconomic transformation of Uganda, including agro industrialisation. Given the dominance of agriculture as a source of livelihood, agro industrialisation (AGI) offers a great opportunity for Uganda to embark on its long-term aspiration of transitioning into a modern industrial economy. Besides other benefits, it provides an opportunity to address the high post-harvest losses, stabilize prices and increase household incomes.

The key projects to spur productivity and thus economic growth include besides others, agricultural post-harvest handling and marketing. Agro processing occupies a very important place in the agricultural value chain, creating backward and forward linkages between the farm and the market, that are expected to stabilize and increase demand for raw agricultural commodities, increase prices, and stimulate increased production/productivity through increased use of improved inputs, increased agricultural research and reduced postharvest losses.

According to the NDP III, post-harvest handling and storage of agricultural commodities has generally improved. For example, community storage facilities, modern grain processing equipment and cold chain infrastructure for dairy have been developed. However, Uganda still has a shortage of standard and modern storage facilities which leads to use of poor-quality storage and subsequently deterioration in quality of the products. Uganda's postharvest losses range from 30 to 40 percent for grains and other staples, and 30 to 80 percent for fresh-fruits and vegetables. Cooperative colleges and colleges of commerce should be engaged to enhance the promotion of buffer stocking and marketing.

Under the planned interventions there are specifically planned activities to: 1) Establish post-harvest handling, storage and processing infrastructure including silos, dryers, warehouses, and cold rooms of various scale and capacities at subcounty, district and zonal levels; 2) Regional post-harvest handling, storage and value addition facilities will be established in key strategic locations; 3) Improve the transportation and logistics infrastructure for priority commodities, like refrigerated trucks and cold rooms; 4) Improve skills and competencies of agricultural labour force at technical and managerial levels in post-harvest handling, storage and value addition.

Besides those long-term national strategies, a number of sector-specific policies emphasize importance of reducing post-harvest losses:

National Organic Agriculture Policy (Ministry of Agriculture of Uganda, 2020)*:* Among the five specific objectives of the organic agriculture policy of Uganda, area 4 "Enhance appropriate post-harvest handling practices and value addition to Organic Agricultural products" emphasizes the importance for proper storage and Value addition on agricultural products to provide alternative intake of the produce – thus reducing dependence on specific markets, creating more jobs along the value chains and increasing the overall foreign exchange earnings borne from the higher value products. This priority area aims to ensure access, availability and affordability of appropriate agricultural technologies and support systems that are scientifically based for post-harvest handling, storage and value addition. Key strategies under this priority area include: (i) promote establishment of demonstration farms and community-based learning centres; (ii) undertake research to develop post-harvest and processing technologies for a diversity of organic products; (iii) promote high quality primary, secondary and tertiary processing of organic agriculture products; (iv) provide incentives for investment in value addition for organic products; (v) support investments in basic infrastructure and utilities to promote agro processing; value addition and storage.

National Agriculture Policy (NAP) (Ministry of Agriculture, Animal Industry and Fisheries, 2013)*:* **The vision of the National Agriculture Policy is "A Competitive, Profitable and Sustainable Commercial and Agriculture Sector".** The overall objective is to promote food and nutrition security and to improve household incomes through coordinated interventions that will enhance sustainable agricultural productivity and value addition; provide employment opportunities, and promote agribusinesses, investments and trade. The NAP also recognizes the importance of reducing post-harvest losses and waste through improved storage, processing, and value addition to enhance food availability and income generation for farmers. As part of this overall objective, the Government aims to promote and facilitate the construction of appropriate agro processing and storage infrastructure at appropriate levels to improve post-harvest management, add value and to enhance marketing; and promote appropriate technologies and practices for minimizing post-harvest losses along the entire commodity value chain.

National Cooperative Policy (Ministry of Trade, Industry and Cooperatives, 2011) **seeks to create a more conducive environment for the co-operatives to expand and diversify their activities**. More attention is given to improving governance, enhancing production, value addition and marketing capacities of the cooperatives. The policy also outlines poor storage facilities and other infrastructure as one of the biggest challenges. Uganda is faced with an acute shortage of modern agricultural commodity warehouses, processing machinery, transport and other equipment. The majority of processing machinery is obsolete. This contributes to high post-harvest losses, estimated between 40-50%, and compromises quality as well as commodity prices. This poses a great challenge to the cooperatives participation in the commodity value chain thus limiting the competitiveness of their commodities. The Policy aims to facilitate cooperative development through effective regulation, continuous technical support and resource mobilization to facilitate faster growth of the co-operative sub-sector play a leading role in poverty eradication, employment creation and socio-economic transformation of the country.

National Agricultural Extension Strategy (NAES 2016/17-2020/21): The Strategic Vision of NAES (Ministry of Agriculture, Animal Industry and Fisheries, 2016) is development of a competitive commercial agriculture sector by transforming it from a predominant subsistence base, with its Strategic Goal to establish and strengthen a sustainable farmer-centred agricultural extension system for increased productivity, household incomes and exports. Among some of the strategies and specific tasks included in the NAES, there are:

- Development of capacity of farmers and other value chain actors in production, agribusiness skills, value addition and post-harvest management through systematic training programs as a way of professionalising the farming community.
- Promoting integration of technical services and other software activities under irrigated agriculture, farm power and machinery, farm planning systems, soil and water management, postharvest handling and agro food processing into field extension services.
- Conducting capacity needs assessments to identify knowledge and skills gaps amongst farmers & other value chain actors in agribusiness, value addition, and post-harvest management.

According to the *National Grain Trade Policy* (Ministry of Trade, Industry and Cooperatives, 2015)**, in Uganda, post-harvest losses range between 26 - 37 percent of the total harvests, mainly due to poor handling methods (at harvesting, inadequate drying cleaning, and grading methods), inappropriate storage methods, and the low storage capacity on farm and at distribution levels in the country.** There are very few standardised warehouses for both grain and processed products. Therefore, there is need to enhance both pre-harvest and post-harvest handling and management of grains. Most of the small-scale farmers, including women, market their products individually, and this has denied them the advantage of cluster/group marketing or marketing cooperatives (such as bulking for small producers, better prices, group branding, etc.). The limited number of collection and bulking centres has also contributed to farmers' inability to bargain for better prices and improved quality of grains along the grain sub-sector. Due to the inadequate capacity of storage facilities and poor post-harvest handling practices, Uganda has experienced an increased loss of the competitive grain market. The National Grain Trade Policy focuses on interventions aimed at improving the supply of quality grain through adoption of postharvest handling best practices, and use of modern storage and value addition facilities. Among basic target indicators, it targets to reduce post-harvest losses from 37 percent to 25 percent.

National Climate Change Policy (Ministry of Water and Environment, 2015) **is Uganda's integrated response to climate change, aiming to ensure a harmonised and coordinated approach towards a climate- resilient and low-carbon development path for sustainable development** As part of the Adaptation response, the following policy priorities are to be pursued: to promote climate change adaptation strategies that enhance resilient, productive and sustainable agricultural systems; to

promote value addition and improve food storage and management systems in order to ensure food security at all times as a factor of resilience. Specific strategies for tackling these sectoral policy priorities are the following: (i) Promote and encourage agricultural diversification, and improved post-harvest handling, storage and value addition in order to mitigate rising climate related losses and to improve food security and household incomes; (ii) Support community-based adaptation strategies through stretched extension services and improved systems for conveying timely climate information to rural populations to enhance the resilience of agricultural systems to the impacts of climate change; (iii) Develop innovative insurance schemes (low-premium micro-insurance policies) and low- interest credit facilities to insure farmers against crop failure due to droughts, pests, floods and other weather-related events.

Uganda's updated NDC (Ministry of Water and Environment, 2022) **highlights that the country's number one priority response to climate change is adaptation in the context of addressing key vulnerabilities in sectors, building adaptive capacity at all levels, addressing loss and damage, and increasing the resilience of communities, infrastructure, and ecosystems.** Agriculture in Uganda is the second largest emitting sector of GHG emission, contributing up to 26.9% the total national emissions, the first being land use and land use change which accounts for over 56% of the emissions. NDC prioritises expanding postharvest handling, storage, value addition and marketing as one of the priority adaptation actions, aiming to reduce the share of post-harvest losses from the baseline 37% to 12% on 2025, and 3% in 2030.

Besides those policies and strategic documents, there are also some of the other national frameworks and plans related to the topic of climate change adaptation and mitigation, including:

- National Climate Change Communication Strategy (UNCCCS 2017-2021)
- Environment and Social Safeguards (ESS) Policy (2018)
- Water and Environment Sector Investment Plan (SSIP 2018-2030)
- National Fertiliser Policy (NFP 2016).

2.4 LEGAL AND REGULATORY LANDSCAPE

Among the key national legal and regulatory documents relevant for the climate change adaptation and mitigation, agriculture and specifically post-harvest food losses, there are:

- **National Climate Change Act** (The Republic of Uganda, 2021), adopted to give the force of law, in Uganda, to the United Nations Framework Convention on Climate Change, the Kyoto Protocol, and the Paris Agreement; to provide for climate change response measures; to provide for the participation in climate change mechanisms; to provide for the measuring of emissions, reporting and verification of information; to provide for the institutional arrangements for coordinating and implementing climate change response measures; to provide for the financing for climate change.
- **Guidelines for Mainstreaming Climate Change Adaptation and Mitigation in Agricultural Sector Policies and Plans** (Ministry of Agriculture, Animal Industry and Fisheries, 2018), developed with the main objective of providing practical, step-by-step guidance for all stakeholders in agriculture sector, including the MAAIF Agencies and Local governments, on how to mainstream climate change adaptation and mitigation in their planning and decision-making processes. The goal of the guidelines is to ensure that interventions developed and implemented within agricultural sector address climate change issues through activities of mitigation and adaptation.

- **National Environment Act** (The Republic of Uganda, 2019) aiming to provide for the management of the environment for sustainable development; to continue the National Environment Management Authority as a coordinating, monitoring, regulatory and supervisory body for all activities relating to the environment; to provide for emerging environmental issues including climate change; to provide for strategic environmental assessment; to provide for procedural and administrative matters; and for related matters.

2.5 GCF COUNTRY PROGRAMME DETAILS

2.5.1 Planned, current, and past climate change-related projects

The Green Climate Fund (GCF) is implementing 13 projects in Uganda (Table 2-1), with a total GCF financing of approximately 106 million USD. The GCF has approved so far 2 country level readiness activities, with a total budget of 3.6 million USD readiness support approved, and 2.1 million USD readiness support disbursed (GCF, 2024).

Table 2-1 - GCF Portfolio in Uganda

Project code	Focus	Geographical scope	Project title
FP220	Adaptation	Africa (Kenya, Tanzania, Rwanda, Uganda)	Africa Rural Climate Adaptation Finance Mechanism (ARCAFIM) for East Africa region
FP211	Cross-cutting	Africa (Benin, Burkina Faso, Burundi, Chad, Democratic Republic of the Congo, Guinea, Guinea-Bissau, Lesotho, Malawi, Mozambique, Niger, Sierra Leone, Somalia, Togo, Uganda, Zambia)	Hardest-to-Reach
FP210	Cross-cutting	Africa (Cote d'Ivoire, Kenya, Rwanda, Zambia, Democratic Republic of the Congo, Nigeria, Uganda)	KawiSafi II
FP190	Cross-cutting	Asia-Pacific, Africa, Latin America and the Caribbean (19 countries)	Climate Investor Two
FP152	Mitigation	Eastern Europe, Asia-Pacific, Africa, Latin America and the Caribbean (40 countries)	Global Subnational Climate Fund (SnCF Global) – Equity
FP151	Mitigation	Eastern Europe, Asia-Pacific, Africa, Latin America and the Caribbean (42 countries)	Global Subnational Climate Fund (SnCF Global) – Technical Assistance (TA) Facility
FP148	Mitigation	Africa (Democratic Republic of the Congo, Mozambique, Rwanda, Sierra Leone, Zambia, Kenya, Nigeria, Senegal, Uganda)	Participation in Energy Access Relief Facility ("EARF")
FP128	Mitigation	Africa, Latin America and the Caribbean (Colombia, Ethiopia, Guatemala, Peru, Uganda, Ecuador, Ghana, Paraguay, Sierra Leone)	Arbaro Fund – Sustainable Forestry Fund

Project code	Focus	Geographical scope	Project title
FP099	Mitigation	Asia-Pacific, Africa, Latin America and the Caribbean (19 countries)	Climate Investor One
FP095	Cross-cutting	Africa, Latin America and the Caribbean (17 countries)	Transforming Financial Systems for Climate
FP078	Adaptation	Africa (Ghana, Nigeria, Kenya, Uganda)	Acumen Resilient Agriculture Fund (ARAF)
FP034	Adaptation	Africa (Uganda)	Building Resilient Communities, Wetland Ecosystems and Associated Catchments in Uganda
FP027	Mitigation	Africa (Benin, Kenya, Uganda, Nigeria, Ethiopia, Namibia, Tanzania)	Universal Green Energy Access Programme (UGEAP)

Of specific relevance for the agriculture sector in Uganda are the projects: FP220 "Africa Rural Climate Adaptation Finance Mechanism (ARCAFIM) for East Africa region", FP034 "Building Resilient Communities, Wetland Ecosystems and Associated Catchments in Uganda", and FP078 "Acumen Resilient Agriculture Fund (ARAF)". From the GCF website, these are the key factors about these programmes:

FP220: In East Africa, climate models indicate a continual increase in average temperatures and more frequent and intense heavy rainfall events. These changes impose significant challenges on the region's farmers, who face increasingly difficult conditions for crop cultivation and livestock management. However, efforts to develop sustainable agricultural practices have been slow due to limited access to Climate Change Adaptation (CCA) funding among farmers in Kenya, Uganda, Tanzania, and Rwanda. There is an urgent call for private sector investments in CCA to drive lasting, market-driven transformations.

Launched in 2023, the ARCAFIM programme aims to introduce a practical financing model to mobilize private sector investments for CCA initiatives in East African micro, small, and medium-sized enterprises (MSMEs) and smallholder farmers engaged in food systems. These entities have the potential to lead sustainable, long-term changes aligned with market demands. The programme facilitates climate adaptation among smallholders and MSMEs by attracting international and local financing, including from regional commercial banks and local financial institutions. This model serves as a proof-of-concept that could be replicated in other regions, offering substantial potential to enhance private sector funding for rural CCA projects on a larger scale.

FP034: This project is projected to run for 8 years (2017 – 2025) with the goal of enhancing the resilience of Ugandan subsistence farmers against climate impacts. Approximately 4 million people residing in and around Uganda's wetlands depend on them for food security. The degradation of wetlands and associated ecosystems is intensifying due to the effects of climate change and other environmental pressures. Funded through grants, this initiative aims to support the Government of Uganda in integrating climate change considerations into wetland management. Climate impacts include heightened variability and extreme weather events such as droughts, floods, high temperatures, and severe storms.

The project seeks to rehabilitate crucial wetlands to enhance ecosystem services like groundwater replenishment, flood regulation, and livelihood improvements for subsistence farming communities engaged in fishing and agriculture. It will also build capacity among local residents to diversify their livelihoods, boosting resilience against climate shocks. Additionally, the initiative aims to strengthen the ability of communities in vulnerable wetland areas to mitigate climate risks and prepare for climate-related disasters, including through the establishment of decentralized early warning systems. FP034 focuses on Uganda's southwestern and eastern regions, which house some of the country's most vulnerable populations, with more than half being women. Although this climate initiative relies on grant funding, it anticipates positive ripple effects in the private sector by creating new income opportunities in rural areas.

FP078: This project is scheduled to span 12 years (2018-2030) and aims to bolster innovative agribusinesses in their early stages that enhance the climate resilience of smallholder farmers.

Agriculture constitutes a significant sector in the targeted countries, with smallholder farmers managing up to 80 percent of farmland and facing high vulnerability to climate change impacts. Ensuring climate resilience is crucial for achieving sustainable, long-term increases in agricultural productivity and incomes for smallholder farmers. The Acumen Resilient Agriculture Fund (ARAF) intends to enhance climate resilience to foster sustained growth in agricultural productivity and incomes for smallholder farmers. The fund seeks to shift the focus of climate change adaptation investments in Africa from grants to long-term capital approaches, enabling smallholder farmers to respond more efficiently and effectively to climate change. It will support innovative social entrepreneurs in micro-, small-, and medium-sized enterprises (MSMEs) by providing aggregation platforms, digital technologies, and innovative financial services tailored to smallholder farmers.

2.5.2 Other relevant projects (on food losses)

The Food and Agriculture organisation of the United Nations (FAO) and the United Nations Development Programme (UNDP) are among the leading UN organisations in Uganda working on the post-harvest food loss reductions. For example, one of the recent projects implemented by FAO and UNDP in Uganda was the project "Fostering Sustainability and Resilience for Food Security in Karamoja sub-region", with an objective to improve food security and the long-term environmental sustainability and resilience of food production systems in the Karamoja sub-region by addressing environmental drivers of food insecurity and their root causes. Besides the general targets, it also aimed to avoid/reduce 480,508 Mt CO_2e of GHG emissions.

Another project, "Waste less food", that was set up in 2016 in Namalu, Uganda, by the Farmers Overseas Action Group (FOAG) in partnership with the local Non-Government Organisation (NGO) called CIRIDE, worked with 300 farmers to reduce food waste on their farms, provide improved grain storage such as air-tight grain bags and metal silos, and maintain a 30-ton community store to ensure food security. Since providing the initial funding to set it up in 2016, the project has become self-sufficient and continues to benefit 300 farmers every year and to fill the 30-ton community store to provide food security for the region. In 2018, FOAG partnered with a local NGO in eastern Uganda, called EADEN, to build a second Waste Less Food project with 400 farmers in Nawandala. And in 2020, they set up our third Waste Less Food project, again with EADEN, this time with 400 farmers in Budhaya (FOAG, 2023).

One of the ongoing World Bank's projects in Uganda, Uganda Climate Smart Agricultural Transformation Project (2023-2028), aims is to increase productivity, market access, and resilience of select value chains in the project area and to respond promptly and effectively to an eligible crisis or emergency. The project interventions will target the northeastern and southwestern regions of the country. The project comprises of five components. The first component, strengthening CSA research, seed, and agro-climatic information systems supports the development, validation, packaging, and dissemination

of context-specific CSA technologies, innovations, and management practices (TIMPs) to target beneficiaries. The second component, promoting adoption of CSA technologies and practices will support investments for upscaling and adoption of CSA TIMPs. The third component, market development and linkages for selected value chains objective is to improve access to remunerative markets through increased access to climate smart harvesting, postharvest handling, storage, value addition, market linkage services, equipment, and infrastructure by higher-level institutions (producer organizations). The fourth component, contingency emergency response component (CERC) will finance eligible expenditures under the immediate response mechanism in case of natural or man-made crises or disasters such as severe droughts, floods, specific pests and disease outbreaks, and severe economic shocks in Uganda. The fifth component, project management, coordination, and implementation will support the management, monitoring, and evaluation of the project.

Some of the local organisations and authorities are also running different local projects and initiatives focused on food loss reduction. For example, The Grain Council of Uganda is working on various projects to improve grain storage and handling facilities. This includes the establishment of warehouses and training for farmers on best practices in post-harvest handling to reduce losses and improve the quality of stored grains.

Another local organisation - Uganda Cooperative Alliance (UCA) - in partnership with various NGOs, is involved in projects that provide training and resources to smallholder farmers on effective post-harvest practices. These initiatives include building community storage facilities and introducing modern post-harvest technologies to improve food quality and reduce losses.

3 Climate Analysis - Adaptation

3.1 COUNTRY CLIMATE CHANGE BASELINE

The vast majority of Uganda is characterised by a tropical climate (Ministry of Water and Environment, 2022). Specifically, under the Köppen Geiger climate classification system, the climate is largely classified as **tropical savanna** (The World Bank, n.d.), with some regions of the south-west of the country classified as **having tropical monsoon and tropical rainforest climate** (The World Bank, n.d.).

Uganda's climate is heavily influenced by the Inter Tropical Convergence Zone (ITCZ), a zone of trade winds convergence from the north and south, creating unique and shifting air circulation patterns, and the El Niño Southern Oscillation (ENSO) phenomenon (The World Bank, 2021). Additionally, Uganda's climate is also influenced by the large-scale Indian Monsoon, the Congo air mass, and the Indian Ocean Dipole (IOD), all of which collectively cause substantial inter-annual variability (The World Bank, 2021).

3.1.1 Temperature

For the most part, Uganda experiences moderate temperatures throughout the year. However, the country's diverse topography influences a fairly wide range of temperatures, from 0°C in the ice-capped Rwenzori Mountain Range and Mt Elgon to 30°C in the north-eastern areas of Gulu, Kitgum and Moroto (The World Bank, 2021). Similarly, precipitation patterns in Uganda also display variance depending on the region. Rainfall distribution has a wide range, with areas such as Karamoja receiving the lowest amounts of average annual rainfall of approximately 400 mm and areas around Lake Victoria and Elgon receiving the highest amounts of average annual rainfall, up to 2 200 mm (The World Bank, 2021).

Historical trends suggest that climate change has already influenced an increase in average temperatures since the 1960s. The major trends since the 1960s include (The World Bank, 2021):

- An increase in average temperature by 1.3°C since the 1960s, or approximately 0.28°C per decade.
- An increase in minimum temperatures by roughly 0.5–1.2°C for this period, and in increase in maximum temperatures by 0.6–0.9°C.
- A significantly increasing trend in the frequency of the number of hot days (a 20% rise between 1960 and 2003), and much larger increased trends in the frequency of hot nights (a 37% rise).

Another source, for a slightly different historical period, corroborates this, noting that records for the 1979 – 2015 period also display increasing temperatures (African Development Bank and the University of Cape Town, 2019).

The trend of increased average temperatures has slowed in the most recent decade, but over a long timeframe indicates a clear rise, as depicted in Figure 3-1, Figure 3-2, and Figure 3-3.

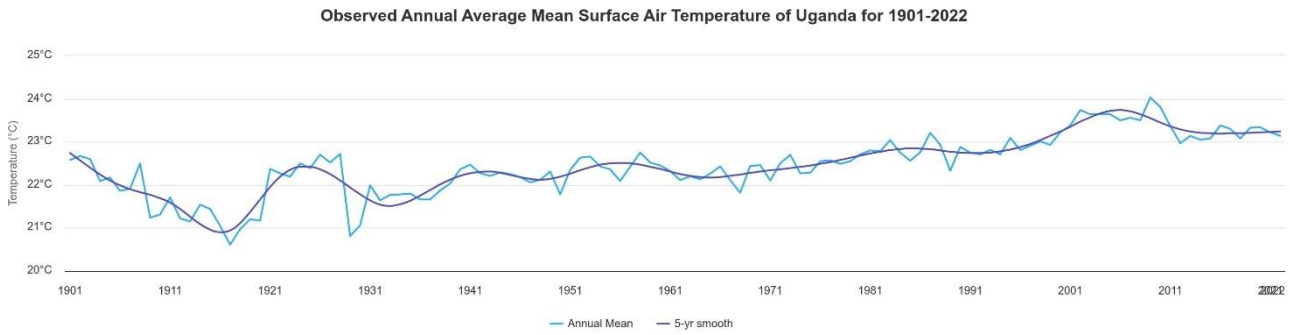


Figure 3-1 - Observed annual average mean surface air temperature of Uganda, 1901 - 2022 (World Bank, Climate Change Knowledge Portal)

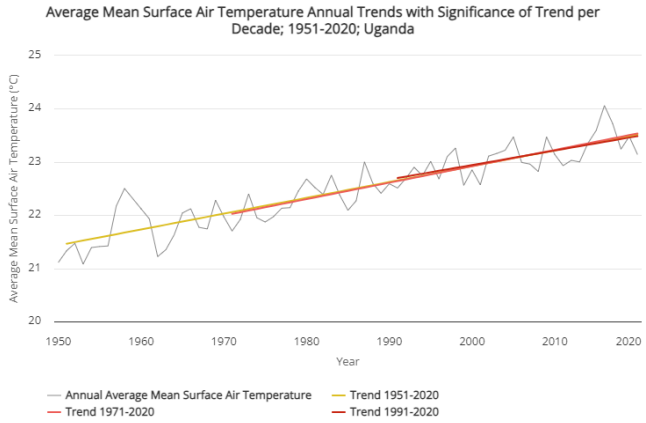


Figure 3-2 - Average mean surface air temperature annual trends with significance of trend per decade, 1951 - 2020, Uganda (World Bank, Climate Change Knowledge Portal)

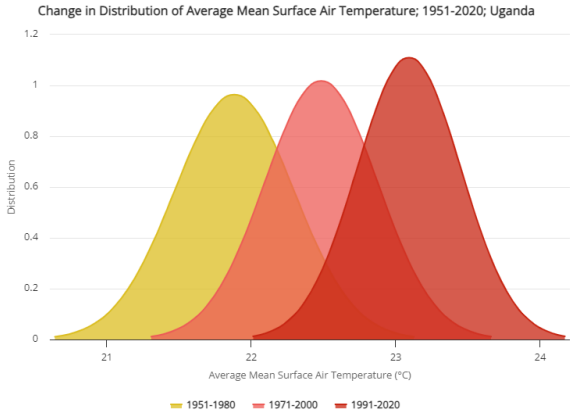


Figure 3-3 - Change in distribution of average mean surface air temperature, 1951-2020, Uganda (World Bank, Climate Change Knowledge Portal)

3.1.2 Precipitation

Rainfall trends in Uganda are variable both in terms of inter-annual rainfall and geographic variability across different regions. Due to the lack of high-quality, continuous, long-term time-series data sets on rainfall in Uganda (and due to the hydrometeorological network being regionally patchy within the country, resulting in gaps in data), precipitation records are inconsistent. Some records suggest a slight decrease over time, while others indicate a marginal increase (The World Bank, 2021). Key trends as reported by one source, the World Bank, include the following (The World Bank, 2021):

- Seasonal rainfall for March, April, and May has decreased by up to 6.0 mm per month, per decade.
- A decline in rainfall has been observed in some parts of northern Uganda, such as in Gulu, Kitgum, and Kotido.
- Droughts have increased in Uganda over the past 60 years. Specifically, over the past 20 years, western, northern and northeastern regions have experienced more frequent and longer-lasting drought conditions.

Another source also acknowledges this variability in rainfall, especially across regions, and indicates that long-term trends in total annual rainfall are less evident in Uganda's Northern region, show a slight increase in the Southern region, and a clearer and statistically significant increase in the Lake Victoria basin, where there has also been a rise in the frequency of heavy rainfall events (African Development Bank and the University of Cape Town, 2019).

Figure 3-4 and Figure 3-5 below demonstrate the historic variability, and the slightly decreasing signal over time.

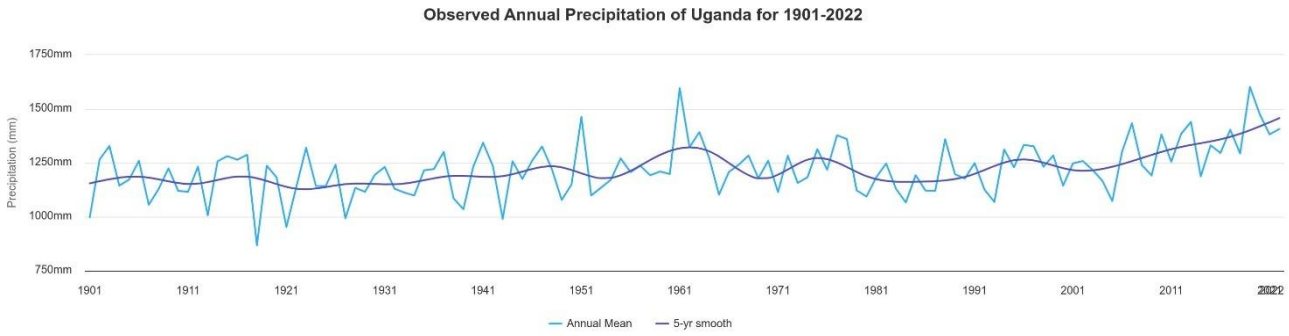


Figure 3-4 - Observed Annual Precipitation of Uganda (1901 - 2022) (The World Bank, Climate Change Knowledge Portal)

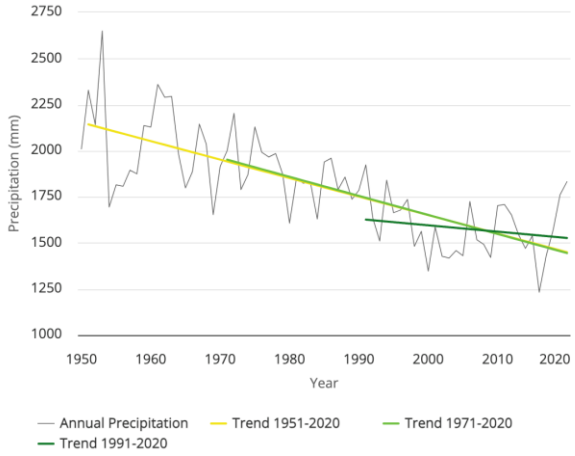


Figure 3-5 - Precipitation annual trends with significance of trend per decade in Uganda (1951- 2020) (The World Bank, Climate Change Knowledge Portal)

3.1.3 Extreme Weather Events

Uganda is prone to climate-related natural disasters. According to the government of Uganda, as much as 90% of natural disasters are climate change-related (Ministry of Water and Environment, 2022). The country has been repeatedly affected by extremes like floods and drought, often within a short period or brief intervals between such events (Ministry of Water and Environment, 2022).

Mudslides, landslides, and flooding are particularly common in Uganda's mountain regions (The World Bank, 2021)**.** Records indicate that such extreme events have increased over the last 30 years; flooding, in particular, has become more frequent, largely due to more intense rainfall (The World Bank, 2021). Over the past two decades, an average of 200 000 Ugandans have been affected each year by climate-related natural disasters (The World Bank, 2021).

The most recent Germanwatch climate risk index for cumulative disaster-related losses between 2000-2019 ranks Uganda as 66th out of 180 countries (Eckstein, Künzel, & Schäfer, 2022). According to the EU's INFORM climate risk index, Uganda's baseline risk level comprises an above-average vulnerability to climate-related hazards (6.7 out of 10), and a high lack of coping capacity (7.0 out of 10) (European Commission, n.d.).

3.2 AGRICULTURE SECTOR CLIMATE CHANGE BASELINE

Agriculture plays a very important role in Uganda's economy. While the sector's contribution to GDP has decreased over the years and stood at an estimated 24% in 2022 (The World Bank, n.d.), agriculture is considered a core sector of Uganda's economy by the government (Ministry of Water and Environment, 2022). It is the largest employer, with over 80% of the rural population and 68% of the total national population employed in the sector (Ministry of Water and Environment, 2022). The contribution to GDP by different agricultural sub-sectors is led by crops (67%), followed by livestock (16%); then fisheries (12%) and finally forestry (4%) (Ministry of Water and Environment, 2022).

The sector is vulnerable to climate change for several reasons. One is the gap between potential levels of yield and actual yields, combined with existing agricultural land not being utilized optimally (currently, only about 35% of the 80% of Uganda's arable land, i.e., land that is already under temporary crops, is cultivated). Furthermore, the labour force is dominated by smallholder farmers – who typically are under-resourced and under-capacitated to cope with shocks and stressors. At the same time, most of the cropping sector is rainfed (approximately 96%), with a minor share of land being irrigated (Ministry of Agriculture, Animal Industry and Fisheries, and the Ministry of Water and Environment, 2017).

3.2.1 Maize

Maize is Uganda's most important cereal crop, providing over 40% of the calories consumed in both rural and urban areas. It has increasingly become a staple food in many parts of the country (National Agricultural Advisory Services, n.d.). Maize is the leading crop in terms of land use in Uganda, accounting for 7% of total harvested area (CCAFS, CGIAR, CIAT, and USAID, 2019). Maize is a direct source of livelihood to over 2 million households, over 1,000 traders (merchants) and over 600 millers. Furthermore, maize has become a major non-traditional export cash crop, which particularly benefits smallholder Uganda's farmers (National Agricultural Advisory Services, n.d.).

Maize is sensitive to changes in temperatures and rainfall. The IPCC's synthesis of global literature on observed climate change impacts on major crops indicates that maize yields in sub-Saharan Africa, have displayed negative trends under a steadily warming climate, as captured in Figure 3-6. Seasonal climate variability and extended dry spells have affected smallholder maize growers in the country, reducing crop yields and increasing the vulnerability of their livelihoods.

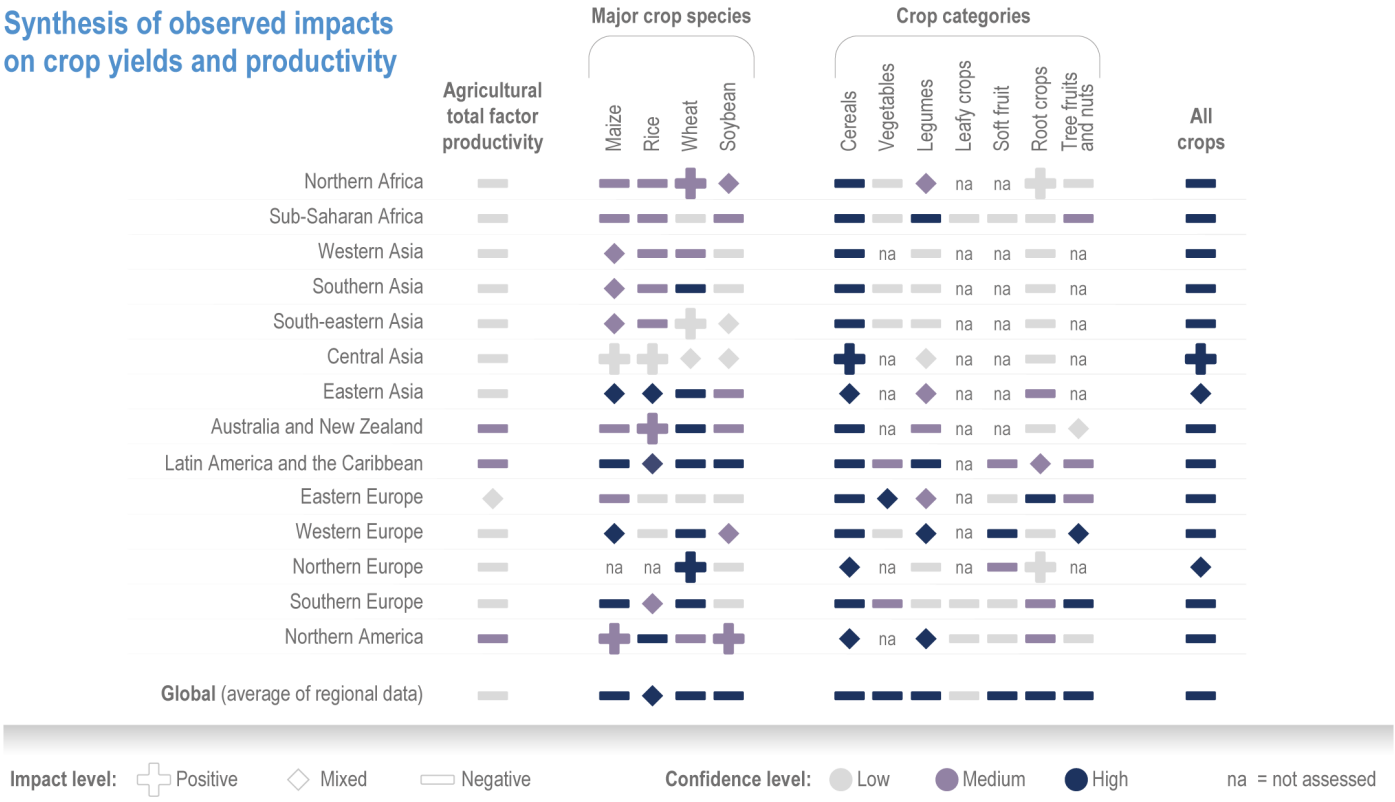


Figure 3-6 - Synthesis of literature on observed impacts of climate change on productivity by crop type and region (IPCC AR6, WG1, Chapter 5, 2022)

Maize production in Uganda is characterized by high dependency on rain, low mechanisation, limited use of improved and high yielding varieties, low use of fertiliser and other inputs and, consequently, low productivity (Kilimo Trust, n.d.). Over the past decade, maize production has increased at an annual average rate of 9.58%, the second highest in the East Africa region (after Rwanda) and it is projected to increase by 272% by 2030. However, the increase in production has been attributed far more to expansion in production area than in productivity (Kilimo Trust, n.d.). Yields, shown in Table 3-1 and Figure 3-7 below, have stagnated in recent years.

Table 3-1 - Uganda's maize production area, volume, and yield, 2014-2024 (USDA, FAS, IPAD)

Market Year	Area ('000 ha)	Production ('000 tonnes)	Yield (t/ha)
2014/2015	1 103	2 763	2.5
2015/2016	1 125	2 813	2.5
2016/2017	96	2.483	2.6
2017/2018	1 079	2 814	2.6
2018/2019	1 288	3 442	2.7
2019/2020	1 317	2 760	2.1
2020/2021	990	2 750	2.8
2021/2022	1 100	2.800	2.5
2022/2023	1.100	2.800	2.5
2023/2024	1 100	2 800	2.5

2024/2025	1 100	2 800	2.5
5-year Average (2019/20 - 2023/24)	1 121	2 782	2.5
Percent Change from 5 Year Average (%)	-2	1	2

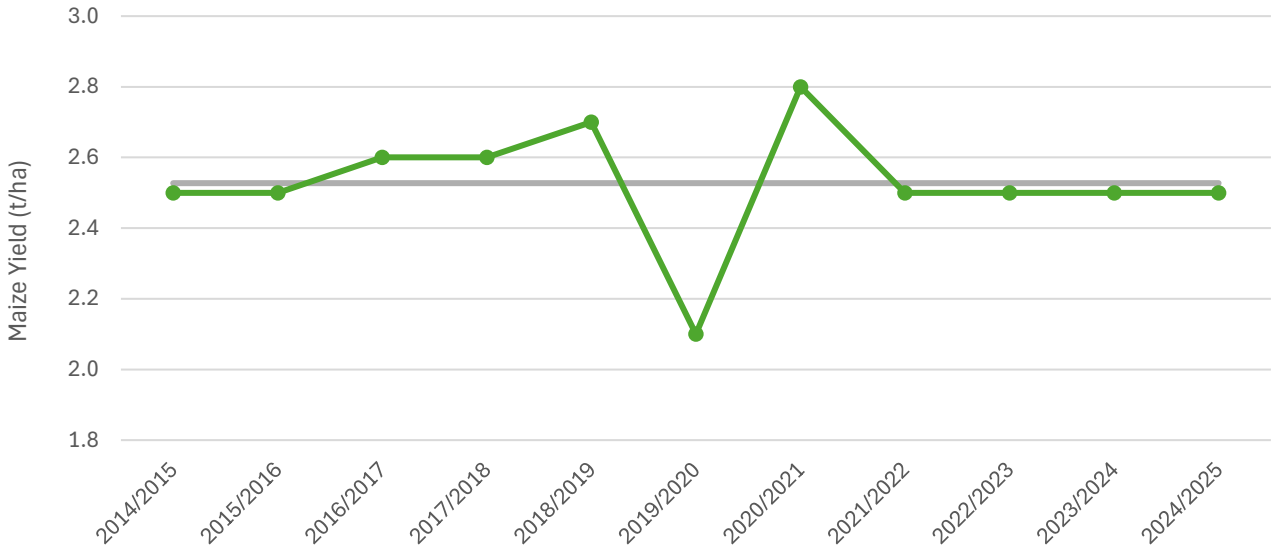


Figure 3-7 - Uganda's maize yields, 2014-2024 (USDA, FAS, IPAD)

3.2.2 Beans

In Uganda, beans cultivation accounts for approximately 5% of the total harvested area and is thus the second largest crop in terms of agricultural land use (after maize) (CCAFS, CGIAR, CIAT, and USAID, 2019). Beans are also grown as intercrops and relay crops accompanying maize and banana. Beans are widely grown as a subsistence but also market crop across Uganda's four regions and are grown in both rainy seasons (IFAD and the University of Cape Town, 2020).

Bean consumption per capita is higher in Uganda than in other East African Community countries and is an important source of affordable dietary protein (Commercial Agriculture for Smallholders and Agribusiness (CASA), 2020). Uganda is now Africa's second-largest bean producer, after Tanzania. Bean production is subject to several factors that create vulnerability, including low soil fertility, limited use of improved seed, poor agronomic practices, and the dominance of smallholder farmers. Most bean production in Uganda is done on small farms ranging in size from 0.4 to 4 ha (Commercial Agriculture for Smallholders and Agribusiness (CASA), 2020).

While production has increased in recent years (see Table 3-2), yields are still lower than their estimated potential. Yields are calculated to be about 1.73 tonnes/ha (FAO, 2022), compared with a potential of 2.5 tonnes/ha (Commercial Agriculture for Smallholders and Agribusiness (CASA), 2020).

Table 3-2 - Uganda's bean production area, volume, yield, and export quantity, 2010-2022 (FAO, 2022)

Year	Area harvested (ha)	Production (tonnes)	Yield (t/ha)	Export Quantity (tonnes)
2010	633 000	949 000	1.50	18 773

Year	Area harvested (ha)	Production (tonnes)	Yield (t/ha)	Export Quantity (tonnes)
2011	653 889	915 445	1.40	28 014
2012	669 000	869 607	1.30	24 494
2013	672 273	941 182	1.40	28 465
2014	674 290	1 011 435	1.50	35 698
2015	674 964	1 079 943	1.60	145 902
2016	483 337	809 640	1.68	197 013
2017	588 185	1 012 406	1.72	262 253
2018	543 511	940 323	1.73	231 849
2019	256 535	437 000	1.70	62 811
2020	453 432	786 000	1.73	72 568
2021	804 073	1 414 574	1.76	184 997
2022	730 817	1 304 563	1.79	26 941
5-year average 2018-2021)	529 147	918 061	1.73	162 896
Percentage change from 5-year average (%)	38%	42%	3%	-83%

3.3 COUNTRY CLIMATE CHANGE FUTURE

For the analysis of future climate risk to the two crops of interest, Maize (corn) and Beans (dry beans) our assessment looks at the 2040-time horizon (a timescale relevant to RE-GAIN's programmatic interventions). To identify future climate conditions that would *(i) signal the major climate-driven threats that could impact post-harvest losses to the crops being considered, and (ii) inform the range and typologies of post-harvest reduction loss interventions to be selected, our analysis examines mean climate projections (using a multi-model ensemble, generated by the sixth Coupled Model Intercomparison Project, CMIP-6).*

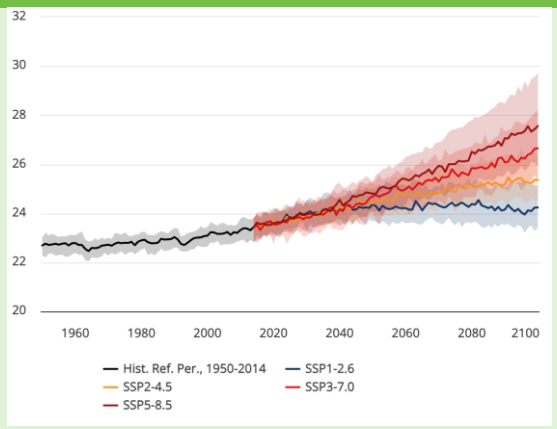
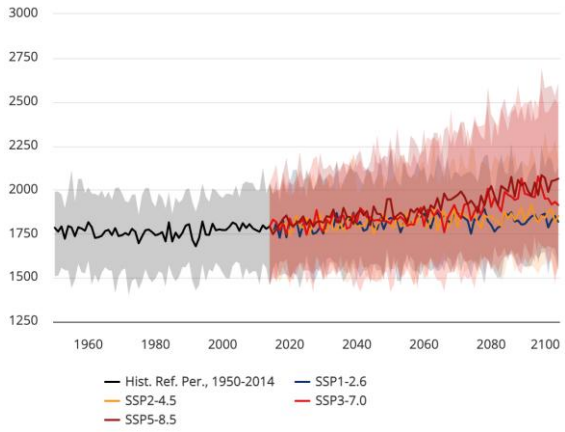
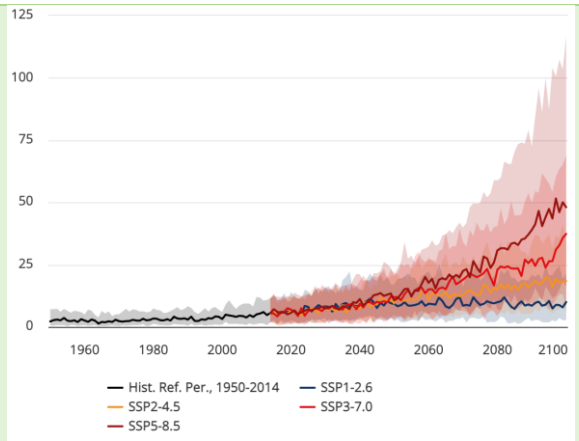
Specifically, we have taken into account two modelled futures based on future shared socioeconomic pathway (SSP) scenarios:

1) **SSP2-4.5** (the intermediate, middle-of-the-road future likely if the current emissions trajectory is followed, with moderate radiative forcing); and
2) **SSP5-8.5** (an extreme future with the highest range of warming this century, likely if no action whatsoever is taken to lower emissions and the world follows a fossil fuel-dominated pathway) (Hausfather, 2019).

We undertook a quantitative component of the climate risk assessment (see Annex Excel workbook "Uganda CCRA") and have integrated the findings from that assessment with qualitative excerpts from relevant sources and literature, coupled

with country-based crop experts, as presented below. Together, this mixed-methods approach offers a holistic view of climate change risk to the two chosen crops in Uganda, focused (to the extent possible) on post-harvest stages of the crop value chain.

Table 3-3: Principal Climatic Variables (The World Bank, n.d.)

Variable Name	In-Country Context Description	Additional information
Average Mean Surface Temperature	Across all future climate scenarios (except SSP1-2.6), the average mean surface temperature in Uganda is projected to increase, relative to the historic baseline (reference period 1950-2014). In our assessment of the projected change of average mean surface temperature in 2040, between the two future scenarios (SSP2-4.5 and SSP5-8.5), we found that the **estimated rise in temperature from the historic baseline is high.**	 *Figure 3-8 - Projected average mean surface temperature under multiple future scenarios (World Bank Climate Change Knowledge Portal: Uganda)*
Mean Precipitation	Across all future climate scenarios, mean precipitation displays substantial variability in climate projections, relative to the historic baseline (reference period 1950-2014). There appears to be a very slight upward trend for the future, however, the increasing signal carries a high degree of uncertainty. In our assessment of projected change in mean precipitation in 2040, between the two future scenarios (SSP2-4.5 and SSP5-8.5), **we found that the estimated change in rainfall from the historic baseline was low (with a minor increasing signal).**	 *Figure 3-9 - Projected mean precipitation under multiple future scenarios (World Bank Climate Change Knowledge Portal: Uganda)*
Number of Hot Days over 35°C	Across all future climate scenarios, the average number of hot days with temperatures rising over 35°C displays a rising trend (except SSP1-2.6). The rise is more pronounced towards the end of the century, but even in 2040, the number of such days increases markedly from the historic baseline (reference period 1950-2014). Given that in the past there were on average 3.2 such days in the year, projections of potentially ~7.5 (SSP 2-4.5) or even ~11 (SSP 5-8.5) such days in 2040 is a notable percentage change. Thus, in our assessment, **we found that the estimated change in the number of hot days over 35°C is very high**.	 *Figure 3-10 - Projected change in number of hot days with temperature over 35°C, under multiple future scenarios (World Bank Climate Change Knowledge Portal: Uganda)*

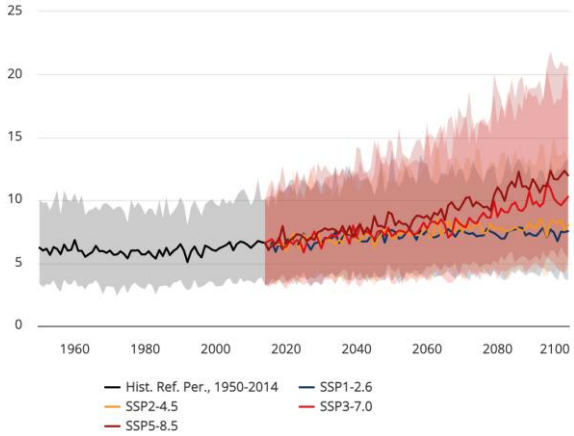
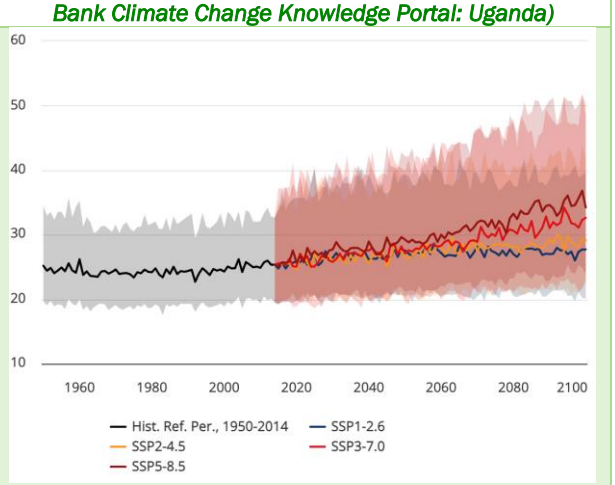
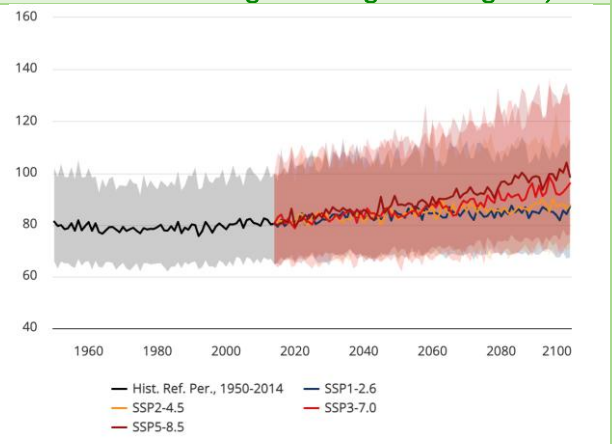
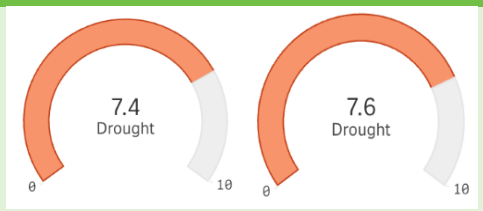
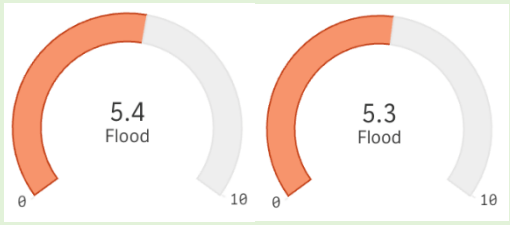
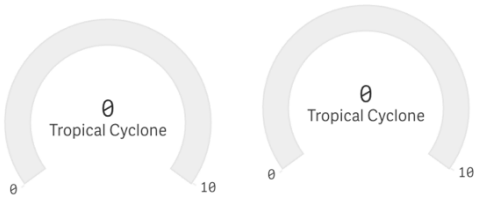
Variable Name	In-Country Context Description	Additional information
Number of days with precipitation >20 mm	Across all future climate scenarios, the average number of days with rainfall greater than 20mm displays a rising trend (except SSP1-2.6). The rise is more pronounced towards the end of the century, but even in 2040, the number of such days increases markedly from the historic baseline (reference period 1950-2014). Given that in the past there were on average 6.05 such days in the year, projections of potentially ~6.86 (SSP 2-4.5) or even ~7.69 (SSP 5-8.5) such days in 2040 is a notable percentage change. Thus, in our assessment, **we found that the estimated change in the number of days with precipitation >20 mm is very high**.	 *Figure 3-11 – Projected change in number of days with rainfall >20 mm, under multiple future scenarios (World Bank Climate Change Knowledge Portal: Uganda)*
Average Largest 1-day Precipitation	Across all future climate scenarios, the average largest single-day (1-day) precipitation (a measure of heavy rainfall events) displays a high degree of variability in climate projections, relative to the historic baseline (reference period 1950-2014). Towards the end of the century, there is a slight apparent increasing signal (except in SSP1-2.6), however, for the 2040 period, the increase is more modest. Nevertheless, in comparison to the baseline, in our assessment of projected change in single-day rainfall, between the two future scenarios (SSP2-4.5 and SSP5-8.5), **we found that the estimated change in rainfall was very high (with an increasing signal).**	 *Figure 3-12 – Projected change in average largest single-day precipitation, under multiple future scenarios (World Bank Climate Change Knowledge Portal: Uganda)*
Average Largest 5-day Precipitation	Across all future climate scenarios, the average largest five-day (5-day) precipitation (a measure of heavy rainfall events, which could trigger flooding) displays a high degree of variability in climate projections, relative to the historic baseline (reference period 1950-2014). The rainfall levels may increase towards the end of the century, however, for the 2040 period, the increase is less stark. Compared to the baseline, in our assessment of projected change in five-day rainfall, between the two future scenarios (SSP2-4.5 and SSP5-8.5), **we found that the estimated change in rainfall was moderate (with an increasing signal).**	 *Figure 3-13 - Projected change in average largest five-day precipitation, under multiple future scenarios (World Bank Climate Change Knowledge Portal: Uganda)*

Table 3-4: Extreme Weather Events and Climatic Disasters (GFDRR, n.d.)

Variable Name	In-Country Context Description	Additional Information
Water Scarcity (Linked to Drought Risk)	Uganda's future water scarcity risk in the face of climate change is regarded as **moderate (medium)** (GFDRR, n.d.). This implies that "there is up to 20% chance droughts will occur in the coming 10 years." (GFDRR, n.d.). Under the INFORM climate risk index tool, future drought risk rises from a baseline of 6.5 (out of 10), under both SSP2-4.5 (to 7.4 out of 10) and SSP5-8.5 (7.6 out of 10) (European Commission, n.d.), which is high.	 *Figure 3-14 – Uganda's future drought risk in 2050 under SSP2-4.5 (left) and SSP5-8.5 (right), on a scale of 10 (INFORM Climate Risk Index, 2024)*
Extreme Heat/Heatwaves	Uganda's future extreme heat risk due to climate change is regarded as **moderate (medium)** (GFDRR, n.d.). This implies that "there is more than a 25% chance that at least one period of prolonged exposure to extreme heat, resulting in heat stress, will occur in the next five years" (GFDRR, n.d.). [Note: the INFORM climate risk index does not provide data for extreme heat/heatwaves.]	N/A
Floods (River and Urban Floods)	Uganda's future flood risk due to climate change (and other factors) is regarded as **high**, including for river flooding (fluvial flooding, where river flows breach the banks) and urban flooding (pluvial flooding, or surface water flooding in built areas where rainfall exceeds infiltration capacity of the ground). "Potentially damaging and life-threatening river floods are expected to occur at least once in the next 10 years" (GFDRR, n.d.). According to the INFORM Climate Change Risk Index, Uganda's baseline risk of flooding (on a 0-10 scale) is 3.9 as of 2022. However, under the SSP2-4.5 scenario for mid-century (2050), this rises to 5.4, and under the SSP5-8.5 scenario, this rises to 5.3 for the same period (European Commission, n.d.).	 *Figure 3-15 - Uganda's future flood risk in 2050 under SSP2-4.5 and SSP5-8.5, on a scale of 10 (INFORM Climate Risk Index, 2024)*
Wildfire	Uganda's future wildfire risk due to climate change (and other factors) is regarded as **high** (GFDRR, n.d.). This suggests that "there is greater than a 50% chance of encountering weather that could support a significant wildfire that is likely to result in both life and property loss in any given year" (GFDRR, n.d.). [Note: the INFORM climate risk index does not provide data for wildfires.]	
Landslides	Uganda's future landslide (or landslip) risk due to climate change (and other factors) is regarded as **high** (GFDRR, n.d.). This indicates that the country "has rainfall patterns, terrain slope, geology, soil, land cover and (potentially) earthquakes that make localized landslides a frequent hazard phenomenon (GFDRR, n.d.). [Note: the INFORM climate risk index does not provide data for landslides.]	

Cyclones	Uganda's future tropical cyclone (or hurricane) risk due to climate change (and other factors) is regarded as **very low.** This denotes that "there is less than a 1% chance of potentially damaging cyclone-strength winds…in the next 10 years." (GFDRR, n.d.) According to the INFORM Climate Change Risk Index, Uganda's baseline risk of cyclones (on a 0-10 scale) is nil (0) as of 2022. Under both the SSP2-4.5 and SSP5-8.5 scenarios for mid-century (2050), this remains nil (0) (European Commission, n.d.)	 *Figure 3-16 - Uganda's future cyclone risk in 2050 under SSP2-4.5 and SSP5-8.5, on a scale of 10 (INFORM Climate Risk Index, 2024)*

3.4 THE FUTURE OF CROP AGRICULTURE UNDER CLIMATE CHANGE

3.4.1 Maize

One of the chief climate impacts on maize (corn) production in Uganda is a projected reduction by the 2050s (The World Bank, 2021). **This is largely due to a rise in average temperatures, as well as more frequent and longer heat waves, plus potentially higher ambient moisture levels.**

High temperatures are not suitable for maize, as maize is sensitive to temperatures above 35°C (Federal Ministry for Economic Cooperation and Development, KFW, GIZ, PIK, 2022)**.** One study estimates that 2090 maize yields in Uganda may decrease by between 7% and 11% due to increased temperatures (Adhikari, Nejadhashemi, & Woznicki, 2015). Crop diseases and pest infestations such as aflatoxin in maize are also expected to increase due to the rising temperatures.

Additionally, erratic rainfall may increase post-harvest storage risks as well as impact crops need to be dried in the sun, like maize (The World Bank, 2021). With moisture being a key factor for aflatoxin growth, aflatoxin contamination is expected to worsen in Uganda if dry-season rainfall increases (USAID, 2013). Furthermore, maize is also affected by short-term water stress and hail (USAID, 2013).

Increasing droughts and unpredictable rainfall patterns are a concern for maize farmers (CropLife, n.d.)**, and are expected to cause a decline in maize yields** (Federal Ministry for Economic Cooperation and Development, KFW, GIZ, PIK, 2022). One study estimates a decline of 6% in maize yields between the years 2000 and 2080 due to drought (Federal Ministry for Economic Cooperation and Development, KFW, GIZ, PIK, 2022). Another indicates that maize yields could decline by as much as 15.6% by 2050 in Uganda as a result of drought (Bwambale & Mourad, 2021).

A study that examined the impact of climate change on growing areas suitable for maize in Uganda found that, overall, there would not be a major reduction/contraction in the total crop suitability area. It did note that all regions are predicted to undergo minor decreases in productivity in both rainy seasons and that the Eastern region is predicted to experience the greatest decrease in productivity in both rainy seasons (with comparatively minor reductions predicted for the Northern and Central regions) (IFAD and the University of Cape Town, 2020).

3.4.2 Beans

Research suggests that all of Uganda's regions are predicted to experience decreased production of beans under climate change (IFAD and the University of Cape Town, 2020). **This is largely due to a rise in average temperatures, as well as more erratic rainfall, plus potentially higher ambient moisture levels.** The most significant negative impacts of climate change are the expected increase in fungal and viral diseases due to intense rainfall (The World Bank, 2021), increased susceptibility to changes in precipitation and temperature particularly during flowering and fruiting (USAID, 2013), decreased production and yields due to prolonged rainfall or drought (Commercial Agriculture for Smallholders and Agribusiness (CASA), 2020), as well as premature ripening of the beans due to increased temperature and sunshine (Ministry of Water and Environment, 2022).

Moreover, just like maize, erratic rainfall may increase post-harvest storage risks as well as impact crops like beans that need to be dried in the sun (The World Bank, 2021).

A study that investigated the potential impact of climate change on the extent of beans-growing areas in Uganda predicted that the total spatial extent of suitable beans-growing areas will likely remain largely unchanged between historical periods (1990-2010) and mid-century periods (2040-2060) (IFAD and the University of Cape Town, 2020). At the same time, the study highlighted that all regions of Uganda are expected to experience negative changes in average suitability for beans in both rainy seasons as a result of climate change (IFAD and the University of Cape Town, 2020). [2]

3.5 RISK ASSESSMENT FOR POST-HARVEST VALUE CHAIN STAGES

3.5.1 Maize

Our analysis of the projected climate change risks to the Maize value chain in Uganda indicates that the most significant **hazards** are an increase in the number of extremely hot days where temperatures breach the 35 °C threshold, the increase in the number of days with rainfall over 20 mm, heavy or intense precipitation (extreme volumes of rainfall in a single day period), flooding (pluvial and fluvial), landslides, and wildfires. To a slightly lesser degree, heat waves and droughts are also relevant.

Ugandan stakeholders at the national and local levels affirmed that for the maize value chain, climate hazards that pose the most substantial risk at harvest and during the post-harvest stages are **heavy or intense rainfall (excessive precipitation), flooding, climate change driven pests and diseases (whose presence is influenced by temperature, humidity, and moisture), and high temperatures (extreme heat), as well as drought. Landslides have also been an increasing threat.**

Specifically, stakeholders in Kampala and Mbale identified the three most important climate change related hazards, corresponding to the three value chain stages RE-GAIN is concerned with, as follows:

Table 3-5 - Top three climate change hazards identified for Uganda's maize value chain, in post-harvest stages, by national and local stakeholders (2024)

Stakeholder Workshop Location	Harvesting Processes	Post-Harvest Handling and Storage	Processing, Transport, and Logistics
Kampala	Excessive rainfall (that damages infrastructure and storage)	Flooding (which damages facilities and infrastructure)	Flooding (which damages roads and transport infrastructure)

[2] *Note to readers: Published literature is scarce on the climate impacts on post-harvest stages of the maize value chain (in Uganda and globally*

	Flooding (that damages crops) High temperatures (extreme heat, which causes damage to the grain, like shattering)	Excessive rainfall (that damages storage, impedes drying, and causes mould) High temperatures (extreme heat, which causes decay of the grain)	Excessive rainfall (that impedes processing and raises moisture) High temperatures (extreme heat, which causes decay of the grain and decrease the shelf life)
Mbale	Excessive rainfall (that affects harvesting and damages the grain) Flooding (that damages crops) High temperatures (extreme heat, which causes damage to the grain) Contamination by pests and diseases (like mould, aflatoxin)	Flooding (which damages storage facilities and infrastructure) Excessive rainfall (that damages storage, impedes drying, and causes mould) Contamination by pests and diseases (like mould, weevils, aflatoxin)	Flooding (which damages roads and transport infrastructure, and causes disruption of mobility) Excessive rainfall (that impedes distribution and marketing) High temperatures (extreme heat, which decreases the shelf life)

A range of factors creates **vulnerability** in the Maize value chain, including very low levels of irrigation and the high reliance on rainfed agriculture, high levels of undernourishment and the prevalence of moderate to severe food insecurity, and low mechanization levels (noting that some of these vulnerability factors apply to the value chain and the agricultural sector as a whole, and are not specific to post-harvest stages of the maize value chain in particular).

Stakeholders in Kampala and Mbale added further granularity and insights to the understanding of vulnerability in the maize value chain, indicating that the principal drivers of vulnerability in Uganda's maize value chain – at harvest and during post-harvest stages – are: **a lack of access to appropriate technology and equipment and facilities (such as adequate drying and storage facilities and other post-harvest infrastructure); lack of necessary knowledge and skills; reliance on traditional, manual methods (rather than mechanized options); and poorly maintained transport infrastructure.**

Specifically, stakeholders in Kampala and Mbale identified the three most important vulnerability factors that make the maize value chain susceptible to climate change risks, corresponding to RE-GAIN's three value chain stages, as follows:

Table 3-6 - Top three climate change vulnerability factors identified for Uganda's maize value chain, in post-harvest stages, by national and local stakeholders (2024)

Stakeholder Workshop Location	Harvesting Processes	Post-Harvest Handling and Storage	Processing, Transport, and Logistics
Kampala	Lack of/limited access to technology, equipment, facilities, and infrastructure Reliance on traditional, manual harvesting / threshing methods (rather than mechanized options) Lack of/limited access to climate information services, weather alerts	Lack of/limited access to technology, equipment, facilities, and infrastructure (especially storage) Lack of / limited information on optimal storage techniques and practices Substandard warehouses that are not climate-robust	Lack of/limited access to technology, equipment, facilities, infrastructure Lack of/limited access to knowledge and skills about packaging tools and methods Poorly maintained roads and transport infrastructure
Mbale	Lack of/limited access to technology, equipment, facilities, and infrastructure Reliance on traditional, manual harvesting / threshing methods (rather than mechanized options) Lack of/limited access to climate information services, weather alerts	Lack of/limited access to knowledge and skills on sorting and grading and storage methods and tools Lack of/limited access to technology, equipment, facilities, infrastructure (especially storage) Lack of / poor early warning systems and climate information	Lack of/limited access to technology, equipment, facilities, infrastructure Lack of/limited access to knowledge and skills about packaging tools and methods Poorly maintained roads and transport infrastructure

In terms of **exposure**, key factors are the share of cropland area under maize, and the large share of the country's labour force engaged in this activity.

Our climate change risk assessment for post-harvest stages of 14 crop value chains, across seven countries, adopted the Intergovernmental Panel on Climate Change's (IPCC's) conceptual framework of risk, i.e., climate change risk being a combination of climatic hazards, vulnerability, and exposure. Our approach was to develop a hybrid, mixed-methods analysis

that combined a quantitative estimation of climate risk (captured in a single composite numerical value, derived as a function of numerically graded levels of hazard indicators, vulnerability indicators, and exposure indicators) coupled with a qualitative elaboration of climate risk (narrative commentary about risks to each crop at each stage of the post-harvest value chain, derived from national and local stakeholder inputs and from literature review).

Overall, in our comparative *quantitative component* of the climate change risk assessment, the higher a crop scored across the numerically graded levels of hazards, vulnerability, and exposure, the higher the combined final numerical value of risk. It should be noted that these quantifications are indicative and were developed to offer a high-level signal of *relative risk* amongst 14 crops that all face significant degrees of risk from climate change. Crops with higher scores are even more at risk from climate change, in post-harvest stages, than crops with slightly lower scores, and thus may benefit from a relatively higher degree of attention for post-harvest loss-reduction solutions, vis-à-vis those slightly less at risk. This is reflected in the ranking that emerged (1 through 14) from the quantitative risk scores (noting that the quantitative signal is *not deterministic of prioritization* and should be read in conjunction with the accompanying qualitative commentary for a fuller picture of risk).

Quantitatively, in our comparative climate change risk assessment, quantitatively the risk level of the maize value chain in Uganda scored: 26.698 out of 125, putting it at rank **6** of the 14 crop value chains similarly assessed.

Table 3-7 - Comparative scoring of climate change risk for crop value chains in RE-GAIN countries

Countries	Burkina Faso	Ethiopia	Kenya	Malawi	Tanzania	Uganda	Zambia
Crops	Cowpea 33.92	Teff 26.44	Maize 26.40	Maize 73.31	Maize 37.33	***Maize 26.69***	Maize 47.90
	Rice 22.23	Wheat 35.25	Beans 13.20	Groundnut 13.84	Rice 17.77	***Beans 25.91***	Soybeans 23.58

For maize grain storage, temperature and moisture are critical variables. High temperature, for example, can cause alterations in the chemical constituents of grains, such as lipids, carbohydrates, and proteins (Coradi, Maldaner, Everton Lutz, Dai, & Teodoro, 2020). Higher temperatures and humidity levels cause deterioration of the grain quality, whereas storage at lower temperatures and humidity levels protects the viability and vigour of maize seeds (Rahmawati & Aqil, 2016). It should be noted that the quality of the harvested seed, including its initial moisture content at the time of harvest, plays a significant role in the post-harvest quality and level of deterioration (Rahmawati & Aqil, 2016). Managing climatic factors during maize storage is also complicated by the interplay between temperature and moisture. For instance, temperature accelerates the reduction in grain moisture but increases deterioration. Wetting, as a result of lower temperatures that may cause condensation during storage periods, also reduces the grain quality (Coradi, Maldaner, Everton Lutz, Dai, & Teodoro, 2020). Extreme weather events during storage can, of course, cause physical damage to storage infrastructure and cause loss of stored grains (e.g., through the infiltration of storage silos with water, or the washing away of stored grains in floodwaters and landslides, etc.).

The impacts of temperature and moisture, as well as extreme weather events, on post-harvest processes like processing, transportation, and distribution to markets (wholesale and retail), are often indirect. These impacts can manifest through both acute (fast-onset) and chronic (slow-onset) damage:

1. **Machinery and Equipment**: Exposure to adverse weather conditions can cause weathering, rusting, decay, and other forms of depreciation, affecting the performance and lifespan of equipment.
2. **Transportation Infrastructure**: Extreme temperatures and weather events can damage roadways, railways, and bridges. For example, roads and rail tracks may melt or buckle, and joints on bridges may warp.

3. **Distribution Networks**: Extreme weather can disrupt supply chains by damaging market locations and other critical infrastructure, leading to delays and inefficiencies in getting products to market

While direct attribution of climate change to post-harvest losses of maize in Uganda is not feasible with current science, it is useful to examine the nature of post-harvest losses and draw some informed inferences about the role of climate.

According to data from the African Post Harvest Loss Information System (APHLIS), **an estimated 16.4% of the maize harvest in Uganda was lost as dry-weight loss in 2022, and over the course of a decade (2013-2022) the average dry-weight loss was 16.95%** (APHLIS, n.d.). Based on decadal data from 2013 through 2022, of the various post-harvest value-chain stages (per APHIS, these are: harvesting/field drying; further drying; threshing and shelling; winnowing; transport from field; household level storage; transport to market; and market storage), the three stages where the largest volume of maize losses occurred in Uganda (in decreasing order) are:

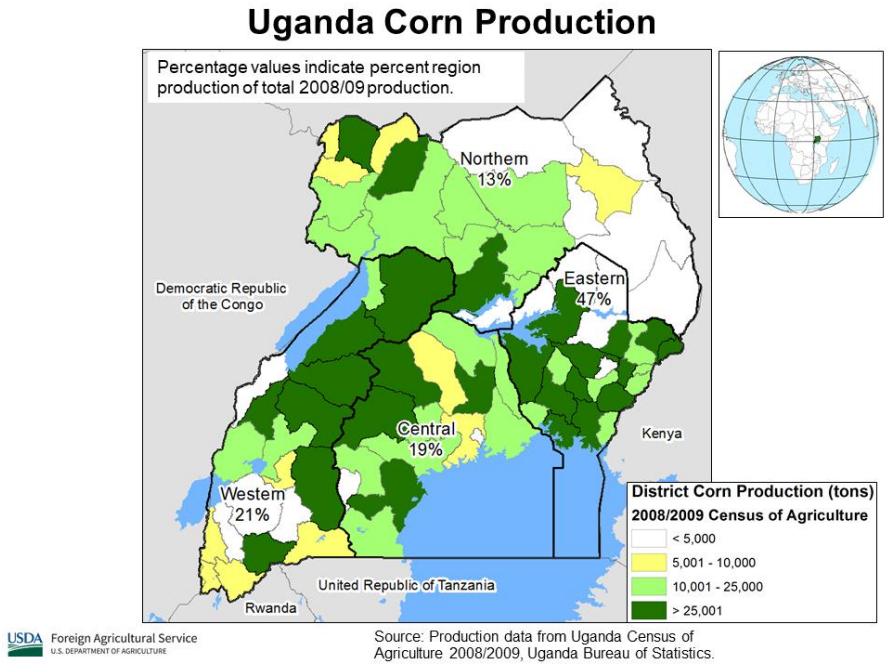
1. **Harvesting and field drying** (by far the stage of greatest losses) – an average annual loss of 6.4% of the crop;
2. **Further drying** – an average annual loss of 4% of the crop; and
3. **Household-level storage** – an average annual loss of 3.85% of the crop.

Together, these three stages represent an average annual loss of over 14% of the total losses in the maize value chain in Uganda, and a vast proportion (84.07%, i.e. a large majority) of the post-harvest losses in the maize value chain. In each of these three stages, **climatic factors are highly relevant**, given how temperature, moisture and humidity, and the prevalence of pests and plant diseases (themselves temperature-sensitive) cause damage to the harvested maize.

With climate change projected to exacerbate these factors, through rising temperatures, more erratic and heavy rainfall events, and the growing risk of floods and heatwaves in Uganda, ***these stages of the Maize value chain are most at risk from climate change, and thus should be prioritized for adaptation (loss-reduction) responses.***

Since these stages (where the largest share of post-harvest losses happens) of the maize value chain are still largely linked to on-farm activities such as harvesting and field drying, and household-level storage, it is fair to surmise that the areas in Uganda where maize is farmed are the dominant geographical locations for these losses, at these stages.

Based on the map of maize growing areas in Uganda (below) (United States Department of Agriculture (USDA), n.d.), the **Eastern Province** (accounting for nearly half, or 47% of maize production in 2008-2009) would be the priority target area for climate-responsive, risk-reduction interventions, potentially followed by the **Western Province** (21% in 2008-2009).



Uganda Corn Production
Percentage values indicate percent region production of total 2008/09 production.
Northern 13%
Eastern 47%
Central 19%
Western 21%
Democratic Republic of the Congo
Kenya
United Republic of Tanzania
Rwanda
District Corn Production (tons)
2008/2009 Census of Agriculture
< 5,000
5,001 - 10,000
10,001 - 25,000
> 25,001
USDA Foreign Agricultural Service
U.S. DEPARTMENT OF AGRICULTURE
Source: Production data from Uganda Census of Agriculture 2008/2009, Uganda Bureau of Statistics.

Figure 3-17 - Uganda: Maize Production by Province, 2022-2023 (USDA, FAS)

Stakeholder workshops in Uganda with agricultural experts at the national and local levels clarified the priority target geographies for RE-GAIN interventions, based on local knowledge of where and to what degree climate change hazards have been impacting the maize value chain, particularly during harvest and post-harvest stages. Insights and guidance from

stakeholders suggest that the priority target areas (regions – all in the Eastern Province) that should be the focus of RE-GAIN's post-harvest loss-reduction climate change solutions are:

- Bugisu: heavily affected by erratic and excessive rainfall, high temperatures, and landslides.
- Busosa: heavily affected by erratic and excessive rainfall and high temperatures.
- Sibei: heavily affected by erratic and excessive rainfall and high temperatures.

3.5.2 Beans

Our analysis of climate change risks to the bean value chain in Uganda indicates that the most significant **hazards** are an increase in the number of extremely hot days where temperatures breach the 35 °C threshold, an increase in the number of days with rainfall over 20 mm, heavy or intense precipitation (extreme volumes of rainfall in a single day period), flooding (pluvial and fluvial), landslides, and wildfires. To a slightly lesser degree, heat waves and drought are also relevant. Increasing temperature along with high humidity would favour bean diseases, such as blights and rust, thus increasing post-harvest losses.

Ugandan stakeholders at the national and local levels affirmed that for the beans value chain, climate hazards that pose the most substantial risk at harvest and during the post-harvest stages are **heavy or intense rainfall (excessive precipitation), flooding, climate change-driven pests and diseases (whose presence is influenced by temperature, humidity, and moisture), and high temperatures (extreme heat), as well as drought. Landslides have also been an increasing threat.**

Specifically, stakeholders in Kampala and Mbale identified the three most important climate change-related hazards, corresponding to the three value chain stages RE-GAIN is concerned with, as follows:

Table 3-8 - Top three climate change hazards identified for Uganda's beans value chain, in post-harvest stages, by national and local stakeholders (2024)

Stakeholder Workshop Location	Harvesting Processes	Post-Harvest Handling and Storage	Processing, Transport, and Logistics
Kampala	Excessive rainfall (that damages infrastructure and storage) Flooding (that damages crops) High temperatures (extreme heat, which causes damage to the bean, like shattering)	Flooding (which damages facilities and infrastructure) Excessive rainfall (that damages storage, impedes drying, and causes mould) High temperatures (extreme heat, which causes decay of the bean)	Flooding (which damages roads and transport infrastructure) Excessive rainfall (that impedes processing and raises moisture) High temperatures (extreme heat, which causes decay of the bean and decrease the shelf life)
Mbale	Excessive rainfall (that affects harvesting and damages the grain); Flooding (that damages crops) High temperatures (extreme heat, which causes damage to the bean) Contamination by pests and diseases (like mould, aflatoxin)	Flooding (which damages storage facilities and infrastructure) Excessive rainfall (that damages storage, impedes drying, and causes mould) Contamination by pests and diseases (like mould, weevils, aflatoxin)	Flooding (which damages roads and transport infrastructure, and causes disruption of mobility) Excessive rainfall (that impedes distribution and marketing) High temperatures (extreme heat, which decreases the shelf life)

A range of factors creates **vulnerability** in the bean value chain, including very low levels of irrigation and the high reliance on rainfed agriculture, high levels of undernourishment and the prevalence of moderate to severe food insecurity, and low mechanization levels (noting that some of these vulnerability factors apply to the value chain and the agricultural sector as a whole, and are not specific to post-harvest stages of the maize value chain in particular). Beans are also often grown as an intercrop with major crops which increases their vulnerability due to additional competition for water, nutrients, and light,

Stakeholders in Kampala and Mbale added further granularity and insights to the understanding of vulnerability in the beans value chain, indicating that principal drivers of vulnerability in Uganda's beans value chain – at harvest and during post-harvest stages – are: **a lack of access to appropriate technology and equipment and facilities (such as adequate drying and storage facilities and other post-harvest infrastructure); lack of necessary knowledge and skills; reliance on traditional, manual methods (rather than mechanized options); and poorly maintained transport infrastructure.**

Specifically, stakeholders in Kampala and Mbale identified the three most important vulnerability factors that make the beans' value chain susceptible to climate change risks, corresponding to RE-GAIN's three value chain stages, as follows:

Table 3-9- Top three climate change vulnerability factors identified for Uganda's beans value chain, in post-harvest stages, by national and local stakeholders (2024)

Stakeholder Workshop Location	Harvesting Processes	Post-Harvest Handling and Storage	Processing, Transport, and Logistics
Kampala	Lack of/limited access to technology, equipment, facilities, infrastructure Reliance on traditional, manual harvesting / threshing methods (rather than mechanized options) Lack of/limited access to climate information services, weather alerts	Lack of/limited access to technology, equipment, facilities, infrastructure (especially storage) Lack of / limited information on optimal storage techniques and practices Substandard warehouses that are not climate-robust	Lack of/limited access to technology, equipment, facilities, infrastructure Lack of/limited access to knowledge and skills about packaging tools and methods Poorly maintained roads and transport infrastructure
Mbale	Lack of/limited access to technology, equipment, facilities, infrastructure Reliance on traditional, manual harvesting / threshing methods (rather than mechanized options) Lack of/limited access to climate information services, weather alerts	Lack of/limited access to knowledge and skills on sorting and grading and storage methods and tools Lack of/limited access to technology, equipment, facilities, infrastructure (especially storage) Lack of / poor early warning systems and climate information	Lack of/limited access to technology, equipment, facilities, infrastructure Lack of/limited access to knowledge and skills about packaging tools and methods Poorly maintained roads and transport infrastructure

In terms of **exposure**, one moderating factor is the relatively small proportion of total arable land under bean cultivation.

Our climate change risk assessment for post-harvest stages of 14 crop value chains, across seven countries, adopted the Intergovernmental Panel on Climate Change's (IPCC's) conceptual framework of risk, i.e., climate change risk being a combination of climatic hazards, vulnerability, and exposure. Our approach was to develop a hybrid, mixed-methods analysis that combined a quantitative estimation of climate risk (captured in a single composite numerical value, derived as a function of numerically graded levels of hazard indicators, vulnerability indicators, and exposure indicators) coupled with a qualitative elaboration of climate risk (narrative commentary about risks to each crop at each stage of the post-harvest value chain, derived from national and local stakeholder inputs and from literature review).

Overall, in our comparative *quantitative component* of the climate change risk assessment, the higher a crop scored across the numerically graded levels of hazards, vulnerability, and exposure, the higher the combined final numerical value of risk. It should be noted that these quantifications are indicative and were developed to offer a high-level signal of *relative risk* amongst 14 crops that all face significant degrees of risk from climate change. Crops with higher scores are even more at risk from climate change, in post-harvest stages, than crops with slightly lower scores, and thus may benefit from a relatively higher degree of attention for post-harvest loss-reduction solutions, vis-à-vis those slightly less at risk. This is reflected in the ranking that emerged (1 through 14) from the quantitative risk scores (noting that the quantitative signal is *not deterministic of prioritization* and should be read in conjunction with the accompanying qualitative commentary for a fuller picture of risk).

Qualitatively, in our comparative climate change risk assessment, quantitatively the risk level of the beans value chain in Uganda scored: 25.91 out of 125, putting it at rank **9** of the 14 crop value chains similarly assessed.

Table 3-10 - Comparative scoring of climate change risk for crop value chains in RE-GAIN countries

Countries	Burkina Faso	Ethiopia	Kenya	Malawi	Tanzania	Uganda	Zambia
Crops	Cowpea 33.92	Teff 26.44	Maize 26.40	Maize 73.31	Maize 37.33	***Maize 26.69***	Maize 47.90
	Rice 22.23	Wheat 35.25	Beans 13.20	Groundnut 13.84	Rice 17.77	***Beans 25.91***	Soybeans 23.58

Estimates of post-harvest losses of beans in Uganda range from 22% (Ariong, Okello, Otim, & Paparu, 2023) **to as high as 40%** (Commercial Agriculture for Smallholders and Agribusiness (CASA), 2020). Both climatic and non-climatic factors appear relevant to harvest and post-harvest losses in the bean value chain in Uganda.

Available literature suggests that a large proportion of such post-production losses are due to poor handling practices (Commercial Agriculture for Smallholders and Agribusiness (CASA), 2020)**.** Smallholders in the value chain lack access to standard equipment and post-harvest handling business services such as drying, threshing and cleaning of beans (Commercial Agriculture for Smallholders and Agribusiness (CASA), 2020). Most post-harvest activities related to beans are manual, with the labour involved largely comprised of women. Threshing is done with sticks and is also assisted by youth. This widespread reliance on rudimentary processes of threshing beans using sticks results in broken grains. Drying is done on the ground with beans heaped in piles or packed in sacks or tins for storage within the household. Only a few semi-commercial farmers have designated storage facilities (Commercial Agriculture for Smallholders and Agribusiness (CASA), 2020). Studies also reveal that poor post-harvest handling often leads to poor produce quality of the beans, including a high prevalence of mycotoxin contamination (fungal attacks) and lower nutritional value.

Moisture is a critical factor as well for post-harvest losses. The recommended moisture content (MC) level for beans at harvest is ideally less than 13%. However, with most farmers using simple storage at the floor level (rather than hermetic storage, or elevated shelves) and unable to manage moisture control, the majority of beans have higher MC, and this drastically reduces their possible storage life (Ariong, Okello, Otim, & Paparu, 2023).

A detailed study of bush beans in particular identified several causes of post-harvest losses in the bush bean value chain in Uganda. Key excerpts from the study are as follows, highlighting both climatic and non-climatic factors that lead to post-harvest losses (Streckler, Blitzer, & Kruijssen, 2022):

> "Bush beans are harvested via uprooting the whole plant. Harvest losses during uprooting are closely linked to the timing of the harvest: if the beans are left on the field for too long in **dry weather**, they tend to dry to such a degree that the pods pop open and spill the beans. If the beans are left on the field for too long in **rainy weather**, they will start rotting…
>
> …Another reason for harvest losses in bush beans is a lack of labour capacity to harvest efficiently, so that farmers are forced to leave crops behind on the fields to spoil. This is despite the fact that harvesting is usually a shared responsibility between men and women, regardless of whether the plot is managed by women (small plots with beans for home consumption) or men (usually larger plots with beans as cash crops). Once the beans are uprooted, they are transported to the farmer's home for further handling. This was mostly done by women farmers interviewed, who typically carried the harvested beans on their heads and walked home, often for hours, since the fields were several kilometres from their homes. Only few women were able to

afford motorised transport. Since the beans were piled up and tied together with bags or banana leaves, physical losses during transport can be significant. Moreover, during transport the beans are exposed to **adverse weather conditions**, particularly **heavy rains**, which can cause the beans to start rotting or germinating.

After transport to the farmers' homes, post-harvest handling – usually done by women supported by their children – takes place by means of drying (of pods), threshing, sorting, drying (of beans) and winnowing. This is when the beans that are rotting or germinating due to poor harvest timing are sorted out.

Post-harvest handling activities offer several opportunities for high losses due to inadequate postharvest equipment (e.g. few or old tarpaulins), post-harvest techniques (e.g. threshing the beans by beating with sticks leading to spillage, breakage and contamination) and external factors (wind, rain, animals eating the crops, etc.). Losses during storage, usually in simple bags in farmers' homes, are also common, especially because of **pests** (weevils, rats, termites) and moisture." (Streckler, Blitzer, & Kruijssen, 2022)

Overall, even with non-climatic factors being significant, the literature seems to point to climatic factors having a substantial role (such as moisture content), with poor handling and storage practices (Tibagonzeka, et al., 2018) making the harvest more susceptible to temperature and moisture-related spoilage, including through fungal infestation and rotting.

While direct attribution of climate change to post-harvest losses of beans in Uganda is not feasible with current science, it is useful to examine the nature of post-harvest losses and draw some informed inferences about the role of climate.

According to the review of relevant available literature, it appears that – beyond harvesting (which itself is a major stage of losses) -- the subsequent stages of the beans value chain where the greatest post-harvest losses occur in Uganda include:

1. **Drying**
2. **On-farm storage**
3. **Field-to-farm/field-to-household transport.**

In each of these three stages, **climatic factors are relevant**, given how temperature, moisture and humidity, and the prevalence of pests and plant diseases (themselves temperature-sensitive) cause damage to the harvested beans.

With climate change projected to exacerbate these factors, through rising temperatures, more erratic and heavy rainfall events, and the growing risk of floods and heatwaves in Uganda, ***these stages of the beans value chain are most at risk from climate change and thus should be prioritized for adaptation (loss-reduction) responses.***

Since these stages (where the largest share of post-harvest losses happens) of the beans value chain are still largely linked to on-farm activities such as drying and storage, it is fair to surmise that the areas in Uganda where beans are farmed are the dominant geographical locations for these losses, at these stages.

Reports indicate that **Southwestern Uganda** is the leading producer region of beans, contributing approximately 44% of national production (the top growing districts within this area include **Isingiro, Kabale, Kamwenge, Kisoro, Ntungamo, and**

Ibanda (Commercial Agriculture for Smallholders and Agribusiness (CASA), 2020). Given these districts' dominant role in production, they would be reasonable to target for climate-responsive, risk-reduction interventions. The map below also suggests that districts in southwestern Uganda be a priority for climate change adaptation measures to reduce post-harvest losses.

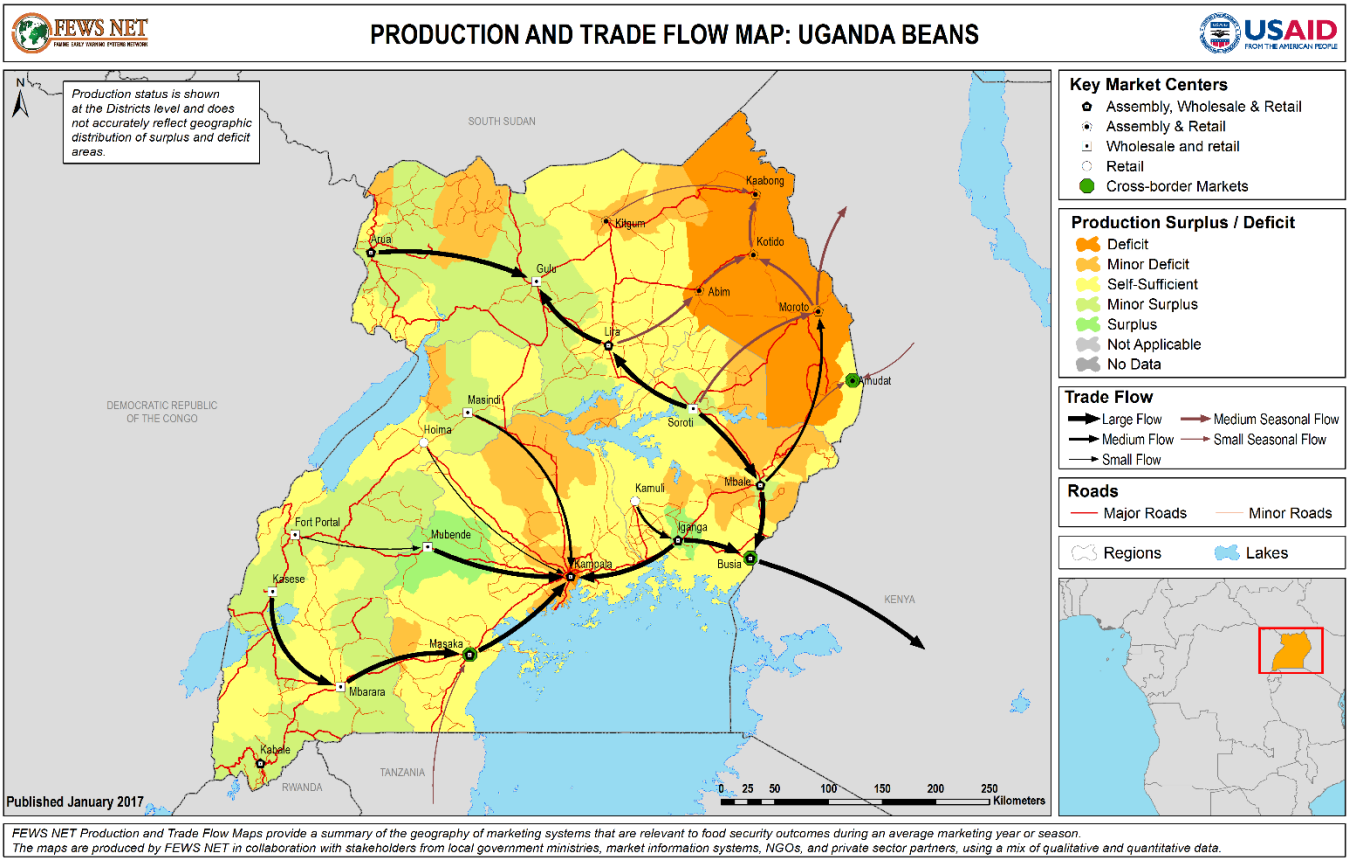


Figure 3-18 - Uganda: Beans Production and Trade Flow Map (Famine Early Warning Systems Network, and USAID, 2017)

Stakeholder workshops in Uganda with agricultural experts at the national and local levels clarified the priority target geographies for RE-GAIN interventions, based on local knowledge of where and to what degree climate change hazards have been impacting the beans value chain, particularly during harvest and post-harvest stages. Insights and guidance from stakeholders suggest that the priority target areas (regions – all in the Eastern Province) that should be the focus of RE-GAIN's post-harvest loss-reduction climate change solutions are:

- Bugisu: heavily affected by erratic and excessive rainfall, high temperatures, as well as landslides.
- Busosa: heavily affected by erratic and excessive rainfall and high temperatures.
- Sibei: heavily affected by erratic and excessive rainfall and high temperatures.

3.6 OVERALL HAZARD RISK ASSESSMENT

We combined the quantitative scores of the hazards component of our risk assessment (i.e., scores reflecting the graded levels of change in hazard prevalence, from the baseline to the future) with qualitative inputs and guidance on climate change risk provided by stakeholders and country agriculture experts (at the national and local stakeholder workshops) to arrive at

an indicative snapshot of risks for the two crops in each country, **from major hazards,** at each stage of the post-harvest value chain. A summary of the post-harvest **hazard risks** for maize and beans in Uganda are presented in Table 3-11.

Table 3-11 - Summary Climate Change Hazard Risk Table for Uganda in Key Crop Value Chains (Post-Harvest)

CROP	CLIMATE HAZARD	*Hazard Risk Level in Stages of Agricultural Value Chain*		
		Harvesting Processes	Post-Harvest Handling and Storage	Processing, Transport, and Logistics
MAIZE	Average temps			
	Rainfall variability			
	Average rainfall			
	Hot days over 35°C			
	Days with rainfall > 20mm			
	Avg. largest 1-day rain			
	Avg. largest 5-day rain			
	Water scarcity			
	Extreme heat / heat waves			
	River and/or urban floods			
	Coastal floods	N/A	N/A	N/A
	Wildfire			
	Landslides			
	Cyclones			
	Sea Level Rise	N/A	N/A	N/A
	OVERALL RISK LEVEL	*HIGH*	*HIGH*	*MODERATE*
BEANS	Average temps			
	Rainfall variability			
	Average rainfall			
	Hot days over 35°C			
	Days with rainfall > 20mm			
	Avg. largest 1-day rain			
	Avg. largest 5-day rain			
	Water scarcity (drought)			
	Extreme heat / heat waves			
	River and/or urban floods			
	Coastal floods	N/A	N/A	N/A
	Wildfire			
	Landslides			
	Cyclones			
	Sea Level Rise	N/A	N/A	N/A
	OVERALL RISK LEVEL	*HIGH*	*HIGH*	*MODERATE*

Key:

High	
Medium	
Low	

4 Climate Analysis - Mitigation

4.1 COUNTRY AND SECTORAL CLIMATE CHANGE EMISSIONS BASELINE

4.1.1 National emissions

Uganda presented its National Greenhouse Gas Inventory (GHGI) in their Third National Communication (Republic of Uganda, 2022) **to the United Nations Framework Convention on Climate Change (UNFCCC), as well as the First Biennial Update Report** (Republic of Uganda, 2019)**.** Agriculture and land-use change and forestry are the largest emitting sectors at ~28 million tonnes CO_2e and ~14 million tonnes CO_2e as of 2021, respectively (Figure 4-1) (Climate Watch, n.d.). While Uganda's national emissions have grown steadily in the last few decades, it still contributes only 0.12% of global emissions as of 2022 (Jones et al, 2024).

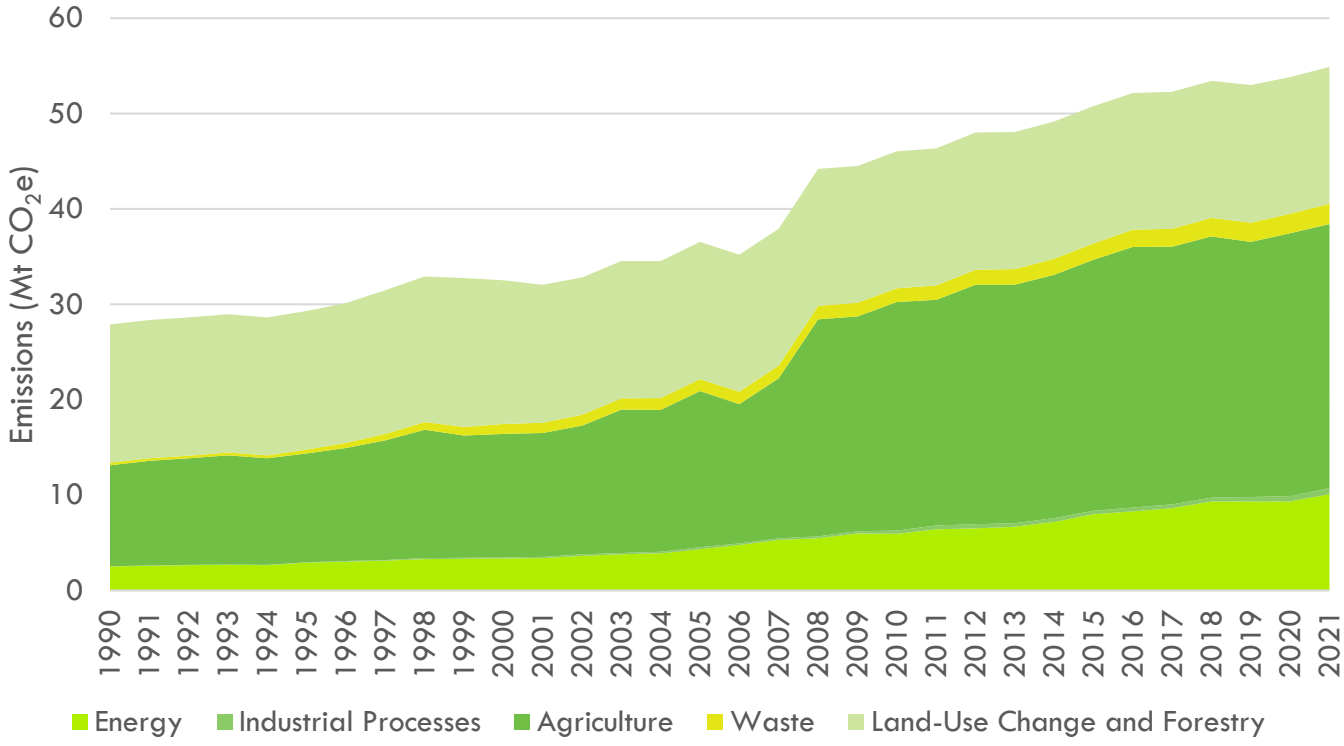


Figure 4-1 - Emissions (all GHG, $MtCO_2e$) across all sectors (total including LUCF) for Uganda (Climate Watch, n.d.)

4.1.1.1 Land use change

By using available land use change datasets, we can ascertain that a loss of forest cover occurred in Uganda between 1960 and 2019, with forest loss occurring over up to ~6% of the land area in AGRA's target regions (see Figure 4-2) (The Hilda+ project, n.d.). Cropland expanded by up to ~13% of these areas in that period (Figure 4-2). Where deforestation occurred between 2001 and 2020, the dominant land uses that replaced forest cover were small-scale agriculture, pastures, and areas with other tree cover or regrowth (Table 4-1) (Masolele, et al., 2024).

Table 4-1 - Frequency (%) of land use types replacing forest where forest cover was lost between 2001 and 2020 in Uganda (Masolele, et al., 2024)

Land Use Type	Northern Region	Eastern Region	Central Region	Western Region
Large-Scale Cropland	3.9%	10.0%	2.8%	3.0%
Pasture	13.6%	4.0%	8.4%	2.9%
Mining	<1%	1.0%	1.1%	<1%
Small-Scale Cropland	53.7%	63.2%	66.0%	82.2%
Roads	1.2%	<1%	<1%	<1%
Other Land With Tree Cover/ Regrowth	13.5%	6.2%	6.3%	3.0%
Plantation Forest	<1%	3.0%	1.5%	1.2%
Coffee	<1%	<1%	<1%	<1%
Settlement	5.6%	2.9%	2.1%	3.7%
Tea Plantation	<1%	<1%	<1%	1.6%
Water	3.2%	4.8%	4.7%	<1%
Oil Palm	<1%	3.3%	3.3%	<1%
Rubber	<1%	<1%	<1%	<1%
Cashew	2.0%	<1%	2.1%	<1%
Cocoa	2.3%	<1%	<1%	<1%

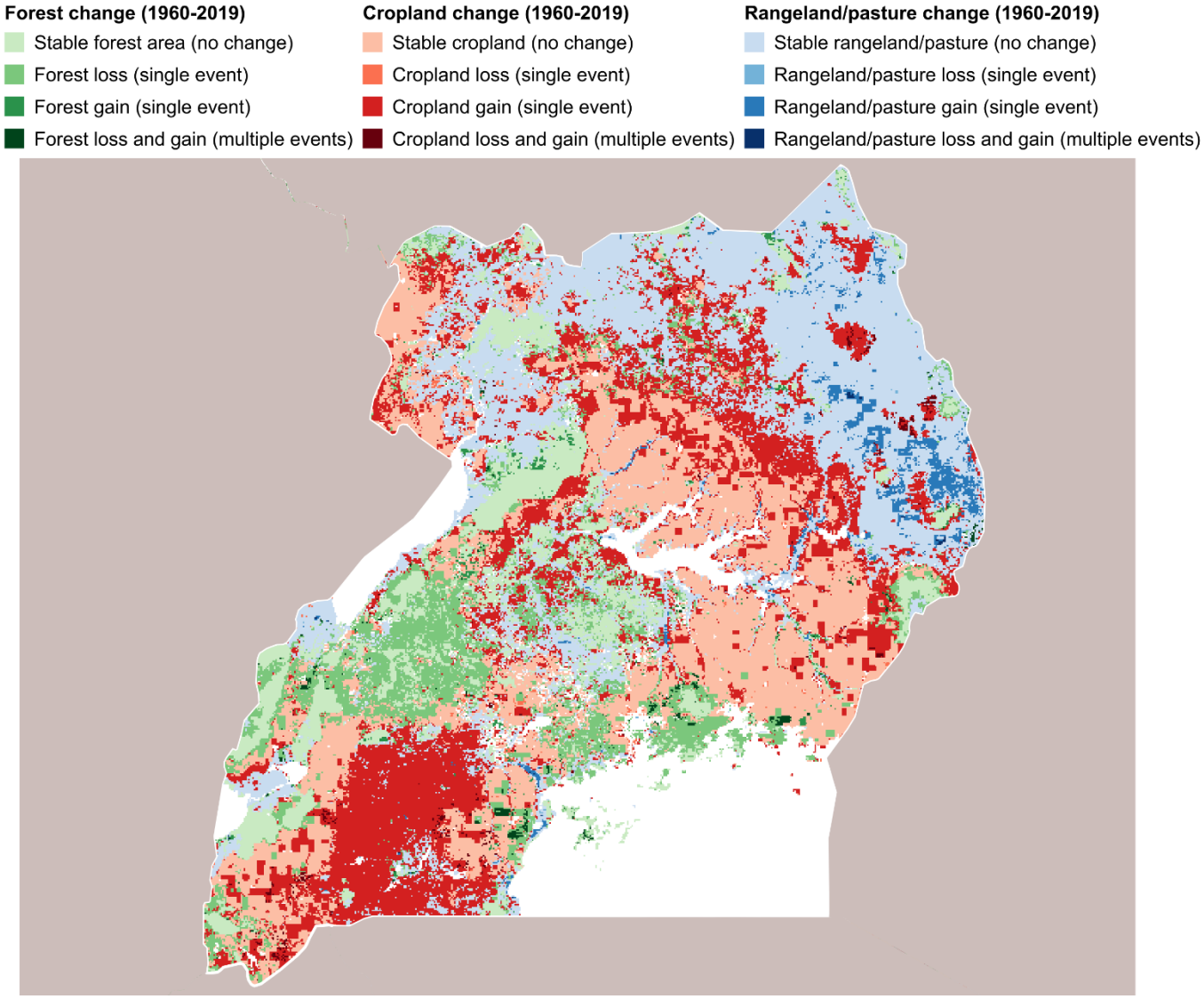


Figure 4-2 - Change in cover for land use categories forest, rangeland/pasture, and cropland in AGRA target regions across Uganda between 1960 and 2019 (The Hilda+ project, n.d.)

4.2 CROP VALUE CHAINS CLIMATE CHANGE EMISSIONS BASELINE

Global analyses indicate that on-farm activities and land use change are the greatest contributors to emissions for commodities related to maize and peas (used here as a proxy for beans) (Poore & Nemecek, 2018)**.** Farm activities account for the bulk of emissions from both crop types (Figure 4-3). Losses account for a significant proportion of emissions (Figure 4-3), particularly in smallholder value chains.

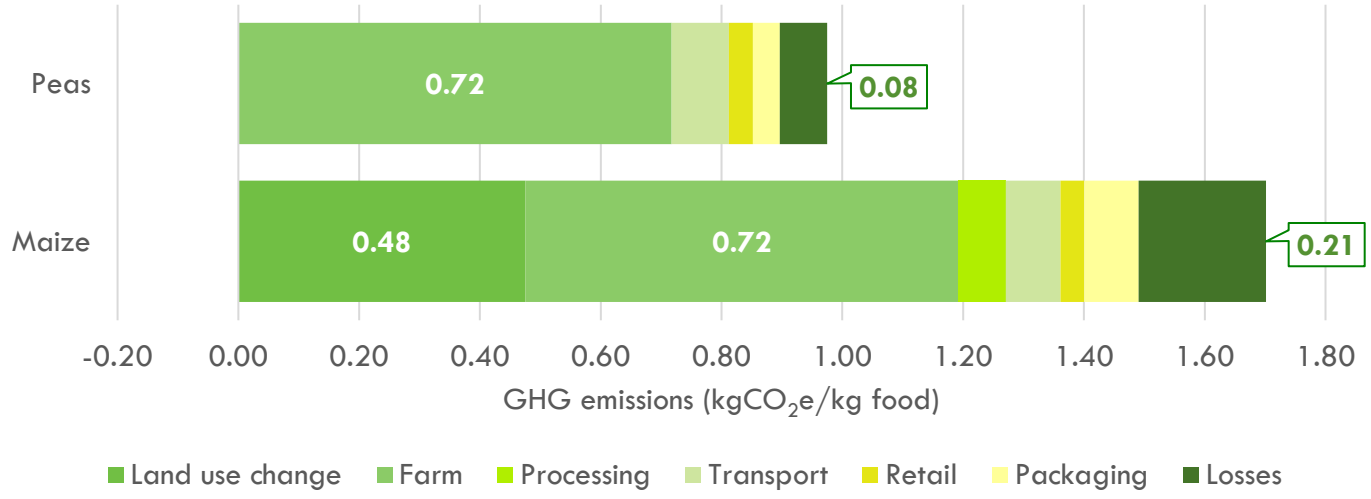


Figure 4-3 - Average GHG emissions (kgCO2e/kg food) for agricultural commodities across value chains (Poore & Nemecek, 2018)

Typical losses and emissions sources across agricultural value chains are depicted in Figure 4-4 below. The bulk of post-harvest losses from field to market occur during processing and on-farm storage of agricultural produce. Pest damage, spillage, inefficient processing and spoilage account for the bulk of losses.

Value chain	Pre-harvest			Post-harvest						
	Land use change	Inputs	Production	Storage	Transport	Storage and handling	Value-added processing	Transport and logistics	Marketing and distribution	End user
Emissions sources	• Deforestation • Burning for land clearing • Erosion and soil loss	• Inputs • Irrigation/ pumping • Fertilisers	• On-farm mechanisation • Management practices	• On-farm storage	• Farm to collection center • Collection center to processing/ market	• Moisture control • Mechanised sorting/ packaging	• Drying • Grinding • Milling	• Warehousing • Road, rail and maritime transport	• Packaging • Retail	• Cooking • Transport • Household appliances
Typical losses	• NA	• NA	• Spillage during manual harvesting, threshing and milling • Leakage from machinery • Poorly maintained machinery	• Pest damage in storage • Contamination and spoilage	• Spillage during transport on farms • Spillage during transport to dealers or storage facilities	• Pest damage • Moisture, mould and spoilage • Storage of untreated grain	• Loss during manual processing • Leakage from machinery • Poorly maintained machinery	• Loss/ spoilage during transport	• Spillage at wholesale sites	• Food waste • Spoilage

Figure 4-4 - Typical sources of emissions and food losses across agricultural value chains (Report Author's Analysis)

On-farm post-harvest losses resulting from climate impacts, inefficient processing practices, poor storage conditions, pests and spoilage present a loss of income to smallholder farmers, as well as affecting household food security. To compensate for post-harvest losses, farmers are likely to expand their agricultural lands, resulting in transformation of forests and other natural vegetation types. This land-use change results in an increase in GHG, both from the practices used to achieve the land use change (e.g., burning), as well as annual emissions from the loss of natural cover and carbon sequestration capacity.

By reducing on-farm post-harvest losses in key crops, the planned interventions will reduce compensatory expansion of agricultural land, thereby avoiding upstream emissions associated with land use change.

4.2.1 Emissions related to food loss

Food loss along agricultural value chains risks not just the loss of edible food, but the waste of the natural resources associated with its production, such as land and water. The inefficient use of natural resources can be considered to have its own environmental footprint, with carbon emissions associated with food loss being among them. Table 4-2 lists calculated emissions associated with food loss for commodity groups in Uganda (Kipkirui, et al., 2023).

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Table 4-2 - Emissions (tCO_2e) associated with food loss for cereals, pulses and oil crops (Kipkirui, et al., 2023) (FAO, WFP and IFAD, 2019)

Country	Cereals	Pulses	Oil Crops
Uganda	269 270	7 680	263 980

4.2.2 Post-harvest losses per crop

4.2.2.1 Maize

On-farm post-harvest losses in the maize value chain occur largely as a result of inefficient harvesting and processing practices, as well as spoilage from pests and mould during storage (Table 4-3). The largest reported losses occur during the harvesting phase, estimated at 6.4% of total production (Table 4-3). This will be further discussed on Chapter 5.

Table 4-3 - Extent of post-harvest food loss and the main causes for maize in Uganda

Value chain stage	Losses (%)	Cause(s)	Reference
Harvesting, field drying	6.4%	Spillage, delayed harvesting to allow cob drying, lack of adequate harvesting tools	(APHLIS, 2024) (FAO, WFP and IFAD, 2019)
Threshing/ shelling	1.3%	Inefficient, labour-intensive hand threshing and shelling, beating cobs results in breakage, spillage, lack of access to mechanized threshers	
Winnowing	N/A	N/A	
Drying	4.0%	Maize dried uncovered, contamination, insect damage	
Transport to farm	2.4%	N/A	
On-farm storage	2.6%	Weevil, moth and rodent damage, mould contamination, breakage, inadequate drying, poor storage practices and inadequate storage facilities	
Transport to market	1.7%	N/A	

4.2.2.2 Beans

On-farm post-harvest losses in the bean value chain occur largely as a result of poor storage practices, with the largest reported losses occur during this stage, estimated at up to 8.5% of total production (

Table 4-4).

Table 4-4 - Extent of post-harvest food loss and the main causes for beans in Uganda

Value chain stage	Losses (%)	Cause(s)	Notes on loss values	Reference
Harvesting, field drying	3.6%	Dry pods shattering, crop left unharvested (oversight/negligence), theft by labourers	The FAO FLWD provides a value for losses during drying from Uganda, which was missing in APHILIS. The FAO, WFP & IFAD (2019) report provides values for losses for beans in Uganda, which were otherwise not available from APHILIS or the FAO FLWD.	(FAO, WFP and IFAD, 2019)
Threshing/ shelling	4.1%	Mechanical damage to beans from beating pods with sticks, spillage and strong wind blowing away beans		
Winnowing	N/A	N/A		
Drying	1.8%	N/A		
Transport to farm	0.7%	Theft by labourers and spillage		
On-farm storage	8.5%	Storage of unthreshed pods results in losses from spillage, pests and rodents and mould		
Transport to market	N/A	N/A		

4.2.3 Emissions associated with food loss

The emissions associated with food loss across the agricultural values chains considered by the RE-GAIN Programme could amount to 681 750 tCO_2e from maize and 7 216 tCO_2e from beans, based on smallholder production values (Figure 4-5, Table 4-5).Figure 4-5

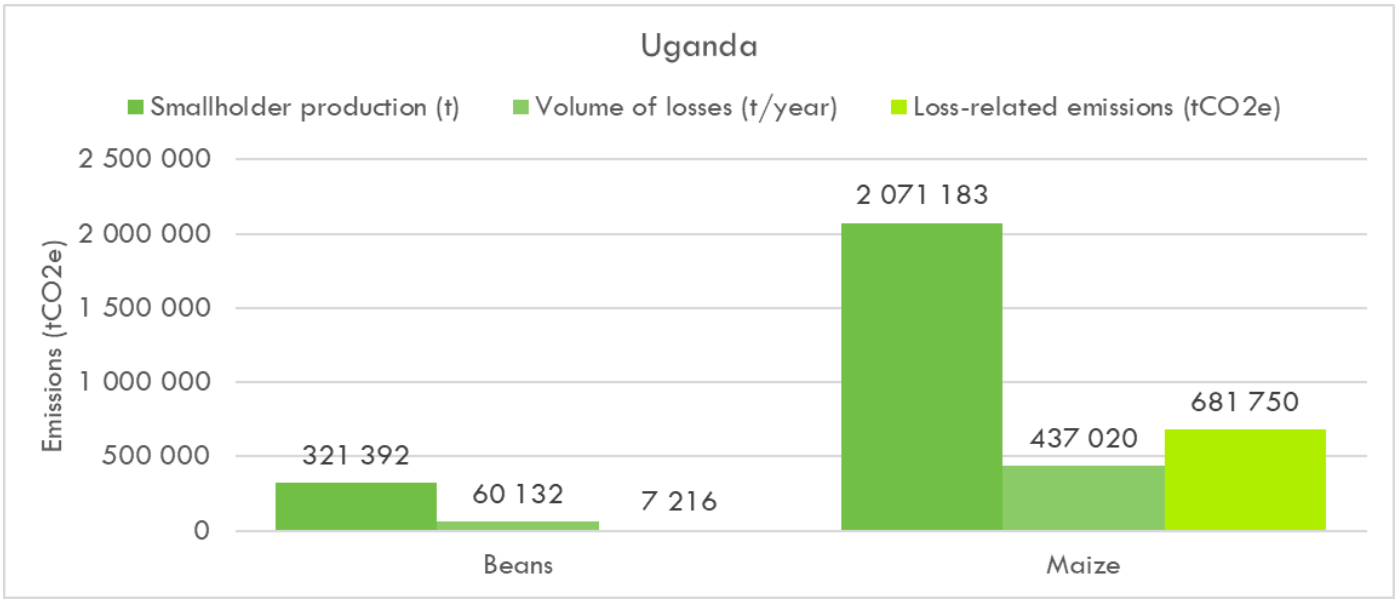

Figure 4-5 - Estimated losses across agricultural value chains for key commodities

A note on the calculation methodology: Using the total maximum losses possible under the loss scenarios presented in the tables above, a possible total loss (%) per commodity can be calculated, as presented in Table 4-5 below. The maximum values were used to represent the worst-case scenario. Smallholder production statistics were sourced from production statistics provided by national statistical offices. Where smallholder production statistics were not made available, the

national production statistics were adjusted to represent the percentage of smallholders in the relevant value chain. The emissions factors used were published in (Porter, Raey, Higgins, & Bomberg, 2016) and have been used in several studies to estimate emissions.

Table 4-5 - Estimated emissions (tCO_2e/t food) calculated using total maximum losses per commodity, total national annual smallholder production (tonnes) and emissions factors for food loss emissions (Porter, Raey, Higgins, & Bomberg, 2016)

Country	Crop	Smallholder production (t)	Loss rate (%)	Volume of losses (t/year)	Loss-related emissions (tCO2e)
Uganda	Beans	321 392	19%	60 132	7 216
	Maize	2 071 183	21%	437 020	681 750
Total		**2 392 575**	**40%**	**497 152**	**688 966**

4.3 COUNTRY AND SECTORAL CLIMATE CHANGE EMISSIONS PROJECTIONS

The GHG inventory developed by Uganda provides projected emissions to 2030 for key sectors under business-as-usual (BAU) and alternative scenarios, which are also used as part of the updated Nationally Determined Contributions (Republic of Uganda, 2022)**.** The BAU emissions projections for Uganda as stated in the NDC (2022) are provided below (Figure 4-6, see also Figure 4-1 above) (Ministry of Water and Environment, 2022). Emissions from the Agriculture, Forestry and Other Land Use (AFOLU) sector are projected to increase between 2020 and 2030 under the BAU emissions scenario, reaching 122.2 $MtCO_2e$ by 2030 (Figure 4-6) (Ministry of Water and Environment, 2022).

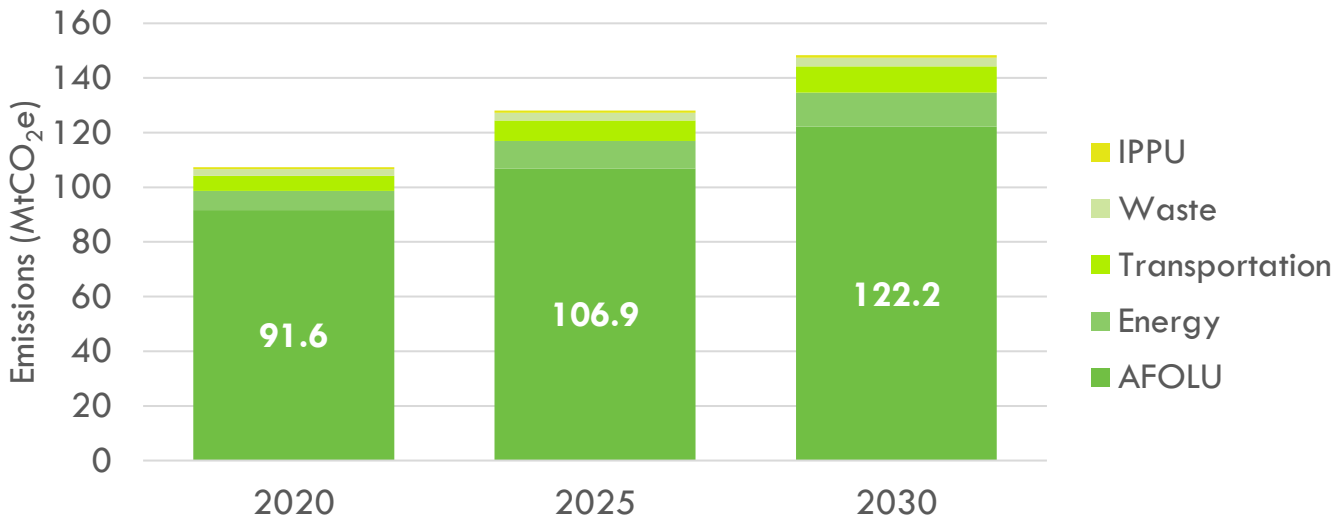

Figure 4-6 - Projected emissions across key sectors in Uganda (Ministry of Water and Environment, 2022)

4.4 CROP VALUE CHAINS CLIMATE CHANGE EMISSIONS PROJECTIONS

The OECD-FAO Agricultural Outlook 2023–2032 highlights the necessity of raising crop production in Sub-Saharan Africa (SSA) over the coming decade to match the projected growth in demand. Production of agricultural and fish products is anticipated to grow by 24% in net value-added terms, but this is only a 2.2% average annual gain, which is lower than the

projected population growth. Most of the projected growth in production is related to an increase in crop production, which is anticipated to account for 70% of the total agricultural value by 2032. The production of food crops in particular, is projected to increase by 27%, as a result of intensification, productivity gains and changes to the crop mix, with a 7% expansion in land used for crop production by 2032 (OECD, 2023).

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The gap between production and demand is concerning given that SSA has arguably the highest concentration of impoverished and undernourished people globally, with low calorie availability per capita across the region (OECD, 2023)**.** The COVID-19 pandemic and the war in Ukraine have exacerbated baseline food insecurity in many areas by increasing costs and disrupting supply (Faruk Urak, 2024). Staple crops contribute approximately 70% of the total calories available to people in SSA as of 2020–2022. Maize, root crops and tubers constitute the bulk of these staple crops. While this is unlikely to change towards 2032, the relative contribution of rice and maize is expected to increase while roots and tubers remain consistent (OECD, 2023).

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Globally, crop losses along the value chain are estimated to increase by 2032, compared to the 2020–2022 period (Figure 4-7). Without significant intervention, losses will undermine regional efforts to improve food security.

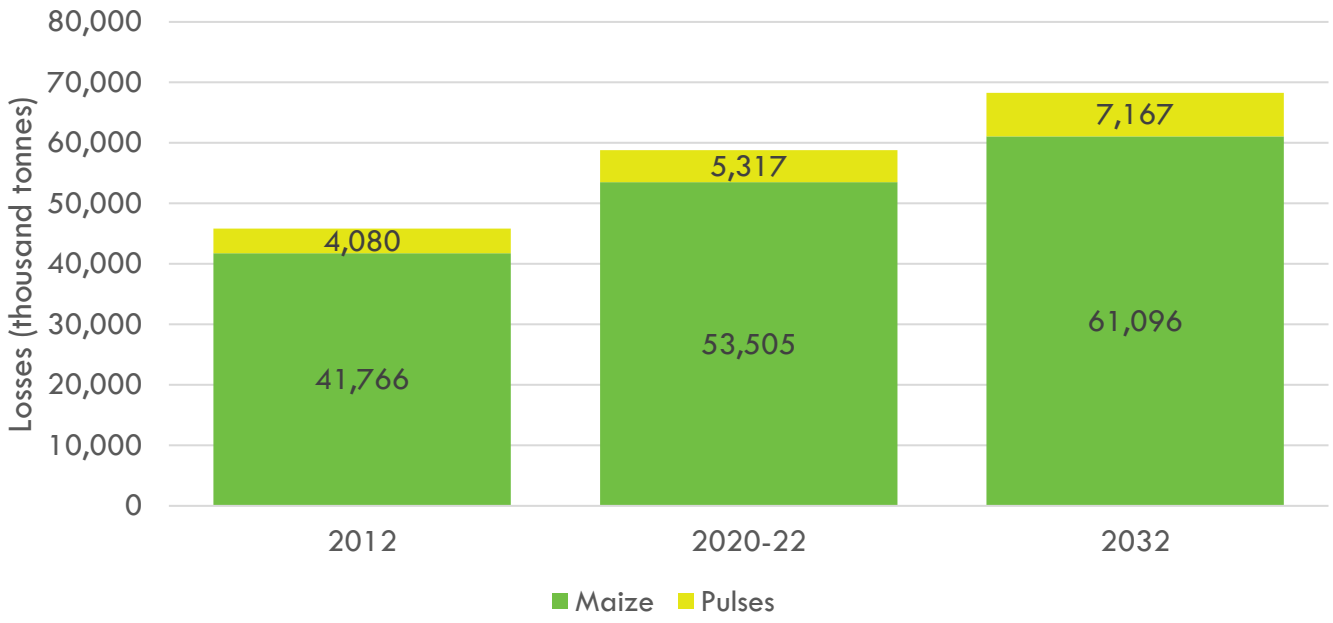

Figure 4-7 - Projected losses across global agricultural value chains for key commodities towards 2032 (OECD, 2023)

By using available estimates of losses as presented in Table 4-5 above, we can make use of the projected estimates for crop yields and harvested area as presented in the OECD-FAO Agricultural Outlook 2023–2032 to calculate potential post-harvest losses and associated emissions for 2032. In Table 4-6 below, projected emissions from post-harvest losses for the year 2032 are presented. These are an underestimation as they do not consider the impacts of climate change on either yields or post-harvest losses. Changing rainfall regimes and increasing temperatures, as well as the associated predicted increases in the occurrence and severity of droughts and floods, are likely to have negative impacts on smallholder agricultural production if no adaptation actions are undertaken.

A note on the calculation methodology: The OECD-FAO Agricultural Outlook provides projected estimates of changes in production, yields and harvested area for key commodity groups across SSA. By using the data available from Table 4-5 and its sources, the OECED & FAO projections were used to calculate estimates for production of the crops in the target countries. These values assume that loss estimates remain unchanged by both adaptation interventions and climate change impacts.

Table 4-6 - Estimated emissions (tCO_2e) for the year 2032 calculated using projected losses per commodity, total smallholder annual production (tonnes) and emissions factors for food loss emissions (Porter, Raey, Higgins, & Bomberg, 2016)

Country	Crop	Projected production 2032 (t)	Projected losses 2032 (t/year)	Projected loss-related emissions 2032 (tCO2e)
Uganda	Beans	388 996	72 781	8 734
	Maize	2 509 400	529 483	825 994
Total		**2 898 396**	**602 265**	**834 728**

Without intervention, emissions related to post-harvest losses on smallholder farms are expected to increase by ~21%. **For Uganda, this could amount to 825 994 tCO_2e for maize and 8 734 tCO_2e for beans by 2032 (Table 4-6).** This presents the minimum expected losses as climate change is likely to exacerbate these numbers.

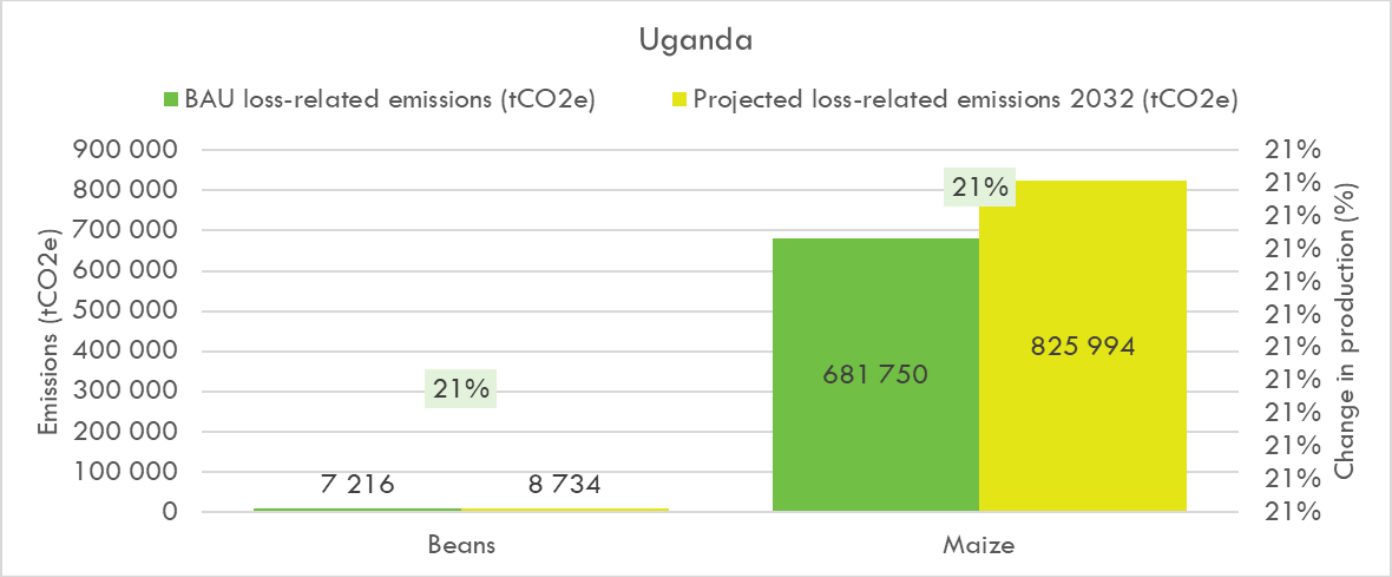

Figure 4-8 - Estimated emissions from post-harvest losses in 2022 and 2032 for key crops across target countries, percentage values indicate projected increase in emissions

5 Design of Food Loss Reduction Solutions

5.1 STOCKTAKE OF FL-RS FOR POST-HARVEST VALUE CHAINS

5.1.1 Maize

Maize is highlighted as one of the ten priority commodities in Uganda's National Development Plan III (NPA, 2020) due to its critical role in food security and nutrition. According to the National Agricultural Advisory Services of Uganda (the National Agricultural Advisory Services of Uganda (NAADS), 2024), maize supplies over 40% of the calories consumed in both rural and urban areas. Small-scale farmers, who make up 80% of the rural poor, are also the primary producers of maize. It is cultivated nationwide and directly supports the livelihoods of over 2 million households, more than 1 000 traders, and over 600 millers. Most small-scale farmers in Uganda grow maize for personal consumption and as a source of income.

Maize production in Uganda is characterized by low input use, low productivity, reliance on rainfall, and minimal mechanization. Over the past decade, maize production has grown at an average annual rate of 9.58%, the second highest in the region after Rwanda, and is expected to increase by 272% by 2030 (Kilimo Trust, 2023). This growth is primarily due to the expansion of the production area rather than improvements in productivity, with average yields not exceeding 2.5MT/Ha and a yield gap of 71%. Maize is the most important grain in Uganda, cultivated by approximately 1.8 million farmers, most of whom are smallholders dedicating less than 2 hectares to maize production for household consumption, food security, and as a source of income (Kilimo Trust, 2023).

In recent years, maize and maize products have become increasingly important in the export market. Maize is also an industrial crop for the animal feed industry and has a high potential for value addition to support the agro-processing industry ((Olaf Erenstein, 2022). Within the Ugandan territory, maize is grown in most parts of the country, but most intensely in Eastern (Kapchorwa, Mbale, Kamuli, Jinja, Iganga), Central (Masaka, Mubende) and Western (Masindi, Kamwenge, Kyenjojo, Kasese, Kabarole) parts of the country, as shown in Figure 3-17 (United States of America - Department of Commerce, 2023).

Uganda has one harvesting period in the North of the country, and two in the South, as shown in Figure 5-1

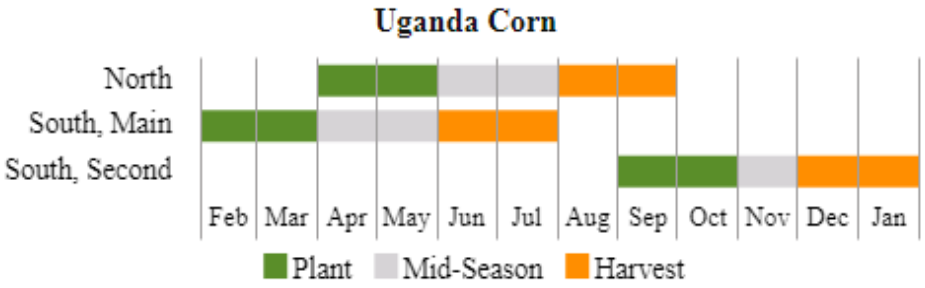

Figure 5-1 Maize harvesting periods in Uganda (USDA, 2024)

Maize production in Uganda is vulnerable to price fluctuations: in 2023, the national average price of maize rose by 20% from January to May. This was due to seasonal patterns and the rapid depletion of stocks caused by reduced production from the 2022 drought. May prices reached record highs, about 10 percent higher than the already high prices from the previous year. Concerns over the 2023 first season harvest performance and continued export demand added further upward pressure (FAO, 2023).

According to (FAOSTAT, 2022)**, over the last 30 years (1992-2022), maize cultivation areas in Uganda have been increasing (Figure 5-2), starting from 438 000 ha in 1992 and resulting in 1 100 000 ha in 2022.** In the meantime, both yields and production volumes have been growing steadily until 2021, with a significant drop in 2022.

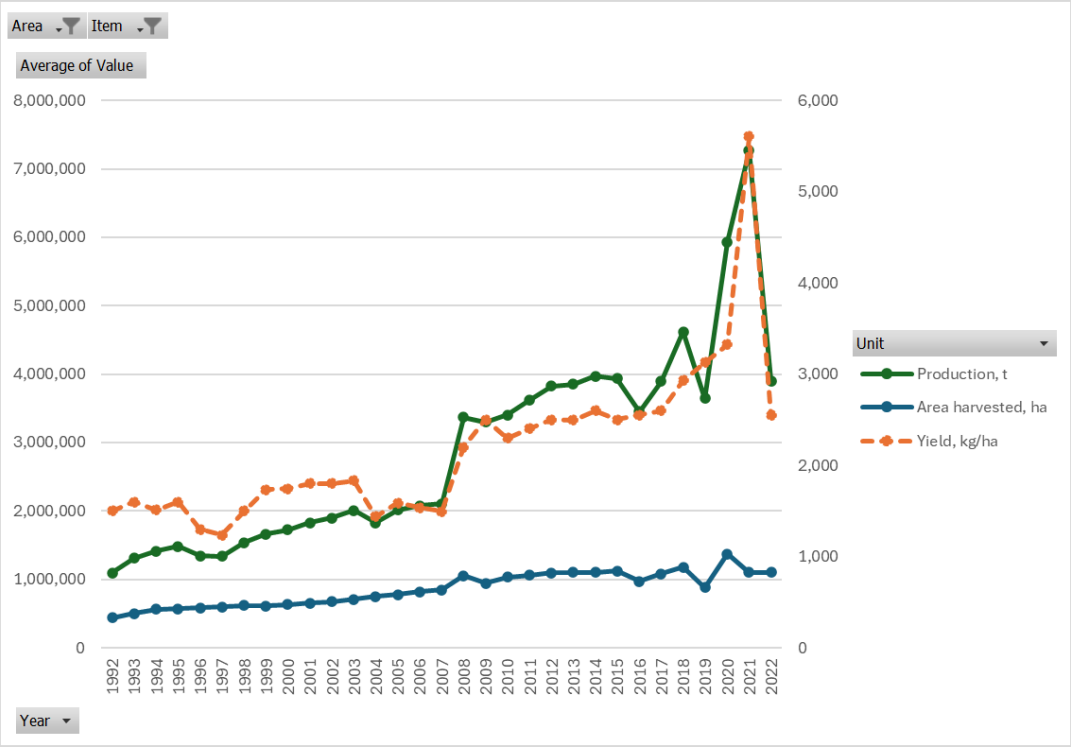

Figure 5-2 Maize Production, Harvest Area and Annual Yields in Uganda, 1992-2022 (FAOSTAT, 2022)

As for the domestic consumption of maize, according to (FAOSTAT, 2022)**, over the last 2 years (2011-2021), Uganda has been quite successful in producing enough maize to satisfy its domestic needs** and consumption (Table 5-1, Figure 5-3) and even export part of the production abroad (FAOSTAT, 2022).

Table 5-1 Maize Production, Domestic Supply and Consumption, Export and Losses in Uganda, 2011-2021 (FAOSTAT, 2022)

Year	Production, 1000 t	Domestic supply quantity, 1000 t	Export quantity, 1000 t	Losses, 1000 t	Food supply quantity (kg/capita/yr)
2011	2 551.00	2 287.00	93.00	120.00	50.11
2012	2 734.00	2 678.00	224.00	129.00	57.09
2013	2 748.00	2 858.00	146.00	130.00	59.42
2014	2 868.00	2 672.00	166.00	135.00	54.27
2015	2 813.00	2 518.00	355.00	132.00	49.35
2016	2 483.00	2 378.00	348.00	115.00	45.62
2017	2 814.00	2 477.00	403.00	129.00	44.79
2018	3 442.00	2 636.00	531.00	157.00	46.26
2019	2 760.00	2 726.00	328.00	123.00	45.81
2020	4 560.00	3 586.00	329.00	204.00	53.29
2021	2 800.00	2 970.00	171.00	129.00	47.28

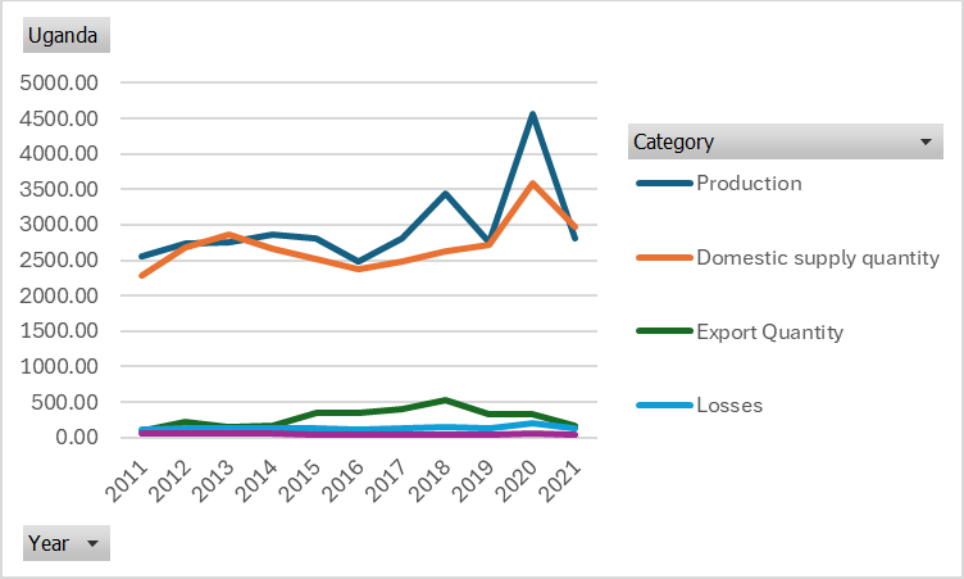

Figure 5-3 Maize Production, Domestic Supply, Export Quantities and Losses in Uganda (1000t) 2011-2021 (FAOSTAT, 2022)

There are governmental initiatives to provide guidelines on harvesting and post harvesting of maize. The Ministry of Agriculture of Uganda created a Maize Training Manual for Extension Workers in Uganda (Ministry of Agriculture, Animal Industry and Fisheries, 2019). This manual provides guidelines for harvesting and postharvest handling of maize. It estimates that Ugandan farmers lose up to 40% of their produce from harvesting to marketing due to poor postharvest handling practices, resulting in low-quality maize.

Maize harvesting practices in Uganda differ depending on its intended use. For fresh consumption, the cobs are picked while still green with grains beginning to harden. For silage, the whole plant is harvested at the milk stage. For grain production, maize is harvested when fully dried and physiologically mature. Signs of full maturity include the maize stalk and cob sheath turning brown, ears drooping, hard grains with a floury texture, grain moisture content between 18-24%, and the presence of a black layer at the kernel tip (Ministry of Agriculture, Animal Industry and Fisheries, 2019).

In Uganda, maize is harvested either manually or mechanically, depending on the scale of farming. Manual harvesting is prevalent for farms under 30 acres and involves pulling ears from the stalk, removing the husks, and usually requires 6-10 people per acre per day. For larger commercial farms, mechanized harvesting with machines such as combine harvesters is preferred. These machines harvest, remove ears, shells, and partially clean the grain simultaneously, ensuring quality, reducing losses, and saving time and labour (Ministry of Agriculture, Animal Industry and Fisheries, 2019).

Premature or early harvesting often leads to shrivelled and spoiled maize. Farmers are advised against throwing cobs on bare ground or using dirty containers, as this heightens the risk of aflatoxin and other contaminants. Similarly, late harvesting should be avoided to prevent pest attacks, grain loss, and rotting. It is recommended to use clean containers or bags for collection and to gather cobs in the field on a tarpaulin or mat to avoid contamination (Baker, Luo, Whitaker, & Xu, 2021).

Postharvest handling practices for maize in Uganda encompass transportation, drying, shelling, packaging, and storage. Depending on the volume, transportation methods include carrying by head, bicycle, motorcycle, or vehicles. Drying involves separating maize grains from the cobs, and preparing them for processing, consumption, and marketing. The shelling process aims to minimize grain damage and loss, as well-dried cobs are easier to shell (Ministry of Agriculture, Animal Industry and Fisheries, 2019).

Farmers commonly use hand shelling, especially with OPV seed, to prevent germ damage and facilitate seed sorting, though it is slow for large quantities. Mechanical shelling includes low-capacity manual shellers (hand and pedal-operated) and motorized shellers (powered by electric motors), which can shell 800-3000 kg per hour. Motorized shellers are increasingly popular, particularly among youth for business purposes, as they reduce postharvest losses. For optimal performance, maize should be dried to a moisture content of 13-14% (Ministry of Agriculture, Animal Industry and Fisheries, 2019).

Various technologies are employed for cleaning maize grain post-shelling, including traditional and mechanical methods, both manual and motorized. Among smallholder farmers, traditional winnowers are prevalent; these tools come in various shapes and materials and utilize the wind to remove lightweight dirt, processing approximately 100 kg per hour. Screens or sieves, typically found at bulking sites and warehouses, are mounted on wooden frames and can clean up to 500 kg per hour by allowing smaller foreign materials and dirt to pass through. Mechanical cleaners, powered by engines or motors, can clean more than 1 tonne per hour with automated sorting based on quality criteria such as colour, size, and shape. These machines are well-suited for seed companies and large warehouses that handle substantial volumes of grain (Ministry of Agriculture, Animal Industry and Fisheries, 2019).

Drying methods and technologies in Uganda include:

1. **Sun Drying**: Maize cobs are dried in the open air on tarpaulins, drying yards, collapsible dryers, drying racks, or cribs. Using a maize crib is recommended for protection against animals and bad weather. Important precautions include regularly turning the grain, keeping animals away, protecting from adverse weather, closely monitoring moisture content, and drying until the grain reaches the required moisture content of 12-13%.
2. **Mechanical Drying**: This method involves blowing hot air to remove moisture under controlled conditions using burning fuel, solar power, electricity, or biomass. It is crucial to ensure the temperature does not exceed 40°C and to maintain appropriate moisture levels through close monitoring (Ministry of Agriculture, Animal Industry and Fisheries, 2019).

Mechanical Drying: This method involves blowing hot air to remove moisture under controlled conditions using burning fuel, solar power, electricity, or biomass. It is crucial to ensure the temperature does not exceed 40°C and to maintain appropriate moisture levels through close monitoring (Ministry of Agriculture, Animal Industry and Fisheries, 2019).

After field drying, maize is transported to the farm for further drying, storage and processing using various methods such as head, bicycle, motorcycle, or vehicles, depending on the volume. Drying involves separating the maize grain from the cobs, which is crucial for processing, consumption, and marketing. To minimize grain damage and loss during shelling, cobs should be well dried (Ministry of Agriculture, Animal Industry and Fisheries, 2019).

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Smallholder farmers in Uganda employ various storage technologies, both traditional and modern, to store maize grain. Traditional methods include mud and wattle granaries, baskets, pots, and jute bags. Modern technologies encompass hermetic storage options such as PVC and metal tanks/silos, cocoons, triple/pics bags, as well as warehouses and grain stores. The choice of storage facility typically hinges on factors like local availability of construction materials, construction expertise, financial resources, the quantity of maize to be stored, desired storage duration, and prevailing weather conditions.

For larger volumes of produce, grain stores, bulking centres, or warehouses are utilized, necessitating sound storage management practices to uphold grain quality. The selection of storage facility is guided by the volume of grain, intended purpose, and financial capabilities of the farmers (Ministry of Agriculture, Animal Industry and Fisheries, 2019).

Smallholder farmers in Uganda employ various storage technologies, both traditional and modern, to store maize grain. Traditional methods include mud and wattle granaries, baskets, pots, and jute bags. Modern technologies encompass hermetic storage options such as PVC and metal tanks/silos, cocoons, triple/pics bags, as well as warehouses and grain stores. The choice of storage facility typically hinges on factors like local availability of construction materials, construction expertise, financial resources, the quantity of maize to be stored, desired storage duration, and prevailing weather conditions. For larger volumes of produce, grain stores, bulking centres, or warehouses are utilized, necessitating sound storage management practices to uphold grain quality. The selection of storage facility is guided by the volume of grain, intended purpose, and financial capabilities of the farmers (Ministry of Agriculture, Animal Industry and Fisheries, 2019).

During storage, maize like other grains can be attacked by insects, moulds, and rodents like rats. Pests form the major problem in storage especially where good storage management practices are not adhered to. The most common grain protection practices in Uganda include fumigation with insecticide and using hermetic bags.

Value addition within Uganda's maize value chain encompasses several activities, including drying, shelling, cleaning, sorting, milling, and fortification. Maize undergoes processing to yield various value-added products such as maize flour, cereals, snacks, grits, starch, and byproducts like maize bran and maize cob meal. Additionally, maize germ extraction allows its use in the food and pharmaceutical industries (Ministry of Agriculture, Animal Industry and Fisheries, 2019).

Maize is predominantly sold in various forms including fresh green cobs, grains, flour, cereals, snacks, and bran for animal feed, targeting local, regional, and international markets. The local market includes individuals, institutions such as schools, hospitals, prisons, and the military, as well as relief organizations (Ministry of Agriculture, Animal Industry and Fisheries, 2019).

Maize food loss data from Uganda from different sources are presented in the Table 5-2 below.

Table 5-2 Comparison of maize food losses in the different stages of the value chain in Uganda

Value chain stage	APHLIS database (APHLIS, 2022)	Average losses (FAO, 2019)
Harvesting/ field drying	6.4%	6.65%
Further drying	4.0%	3.91%
Threshing and Shelling	1.3%	1.32%
Transport from field	2.4%	2.37%
Drying on-farm	-	4.00%
Household-level storage	2.6%	2.51%
Transport to market	1.7%	1.65%
Milling, processing	-	5.00%
Market storage	2.7%	2.65%
Overall:	**21.1%/ 18.4% with market storage**	**30.1%**

As we can see from Table 5-2, the most critical value chain stages in terms of food losses for maize in Uganda are harvesting, household (farm level) storage, and drying. FAO also identifies milling as a critical loss point (CLP). Maize is susceptible to moisture, aflatoxin development, and attacks by pests and rodents during storage. Therefore, it is crucial to ensure the maize is properly dried to a moisture content of 12-13% before placing it into storage facilities (Ministry of Agriculture, Animal Industry and Fisheries, 2019).

A general overview of the maize value chain in Uganda, covering key stages, processes, stakeholders, climate data, and potential solutions to reduce food losses are presented in Table 5-3.

Table 5-3 Overview of Maize food losses in Uganda in the value chain's different steps, including relevant parameters and suggested solutions

FSC Stage/ process	Processes	% losses (APHLIS, 2022)	Cause of Losses	Affected stakeholders	Climate aspects	Suggested solutions
Harvesting						
Harvesting/field drying	Cutting/gathering the cobs, manually or using mechanical harvesters Field drying in stooks	6.4%		Farmers	Heat stress for workers/farmers and animals, increased humidity/ moisture of crops and fungi development Rains, winds	Capacity building training on harvesting techniques and harvesting tools Capacity building on drying
Hauling	Transport from the field to the farm, carrying by hand or by using various vehicles	2.4%		Farmers	Rains, winds	Using trucks and other types of vehicles
Post harvest processes (on-farm)						
Threshing / shelling of cobs	Manual or mechanical shelling, using manual and mechanical shellers	1.3%	Mechanical damage	Farmers	Rains, winds, temperature	Capacity building on threshing technique, or using mechanical threshers
Drying	Additional drying using cribs, tarpaulins, and similar solutions	4.0%	Mold, insects, rodents, livestock foraging	Farmers	Rains, winds, temperature	Plastic sheets and tarpaulins, rectangular cribs
On-farm storage	Storage in bags, silos, or baskets	2.6%	Mold, insects, rodents	Farmers	Heat/ high temperatures	Metal and plastic silos, sheds, plastic and hermetic bags, baskets and cribs, solid brick bins, Insecticides/ fumigation
Primary processing	Grinding, hulling, pounding, milling, etc. using manual, partially mechanised or	5.0%/ Not required	Spillage, contamination	Millers		Improved processing techniques and equipment

FSC Stage/ process	Processes	% losses (APHLIS, 2022)	Cause of Losses	Affected stakeholders	Climate aspects	Suggested solutions
	fully mechanised small-scale and industrial mills					
Transport, logistics, further processing						
Collection from farm	Aggregating and grain collection; transportation to collection centres/ aggregation depot/ markets using vans and trucks of various capacity	1.7%	Spillage	Aggregators/ collectors and traders		Plastic hermetic bags; non-hermetic polypropylene bags
Grading and packing	Sorting, pre-cleaning, re-packaging and packaging			Collectors and traders		
Storage	In bulk and/or in bags	2.7%	Spillage, qualitative losses	Storage companies, warehouses		Plastic hermetic bags, non-hermetic polypropylene bags. Insecticides/ fumigation
Wholesale	Packaging, storage, transportation to the sale points (markets, supermarkets)		Spillage, qualitative losses	Traders		
Secondary processing	Further processing into roller meal, flour, animal feed, products for snack and brewing industry, etc.		Quantitative losses	Secondary processors		

5.1.2 Beans

Bean production in Uganda reached around 670,000 metric tonnes across 1.13 million hectares, with an average yield of 0.8 metric tonnes per hectare. Beans play a critical role as a protein source for Ugandan households, contributing 25% of the total dietary calorie intake and 45% of the protein intake. They are cultivated extensively across the country (UNDP, 2014).

Bean production in Uganda is primarily small-scale, with farmers typically cultivating less than 2 acres, constituting between 60% to 90% of the production. Despite the potential yield ranging from 700 to 1,500 kg per acre depending on the variety, the average production remains around 250 kg per acre. The production system is marked by minimal input use, especially in terms of seed and pesticides, with many farmers relying on seed saved from previous harvests (the National Agricultural Advisory Services of Uganda (NAADS), 2024).

As for domestic trade, Kampala is the main consumption and transit market. There are major flows of beans from production areas to Busia (for their export to Kenya and South Sudan) and to Gulu and Lira, from where they are further directed to Kampala and the Karamoja sub-region (Figure 3-18 - Uganda: Beans Production and Trade Flow Map (Famine Early Warning Systems Network, and USAID, 2017)) (Famine Early Warning Systems Network, and USAID, 2017).

According to (FAO, 2019)**, beans (Phaseolus vulgaris) rank as the second most cultivated crop in Uganda after maize**. More than 1 million households engage in bean farming, collectively dedicating around 1 million hectares of land annually to this crop. Traditionally grown for household consumption, dry common beans are increasingly becoming a significant commercial crop. Among bean producers, the average land size dedicated to bean cultivation ranges from 0.1 hectares to 4 hectares per household, with an average of 0.4 hectares per household.

Beans in Uganda are cultivated in two main seasons: from March to June and from August to October. According to 2020 data from the (Uganda Bureau of Statistics, 2022b), 39% of agricultural households in the country grew beans during the first season, and 46% did so during the second season.

According to (FAOSTAT, 2022)**, domestic production of dry beans in Uganda fluctuated between 2011 and 2022, with the majority of those produced beans consumed on the national level Figure 5-4).** But as we can see from the available data on harvested area, that has increased 1.5 times since 1992 (Figure 5-5), with annual yields increasing steadily over the years, particularly since 2008. Despite these increases, unpredictable weather conditions compromising on bean yield, limited access to improved inputs due to low incomes and limited access to credit expose producers to the threat of pests and diseases, poor farming methods leading to soil degradation, low productivity and limited access to proven post-harvest technologies leading to high post-harvest losses.

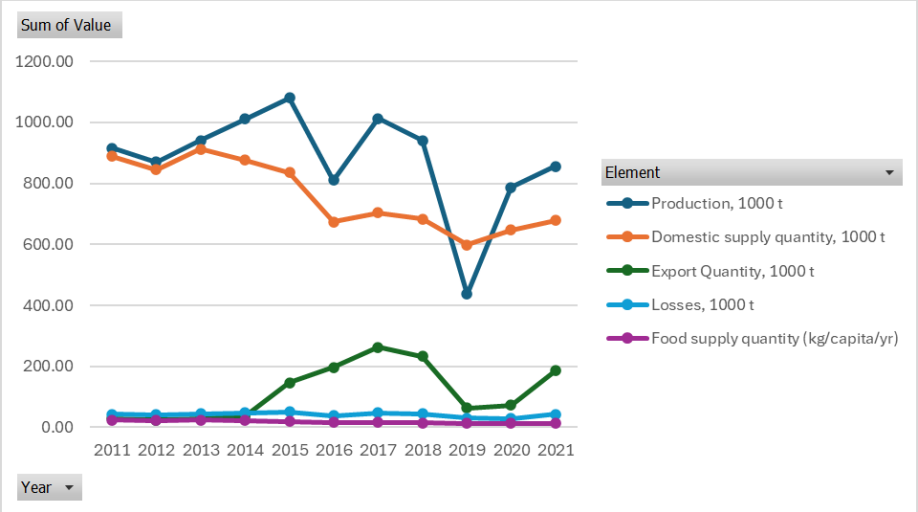

Figure 5-4 Dry beans in Uganda: domestic supply, production volumes, losses and consumption per capita in 2011-2022 (FAOSTAT, 2022)

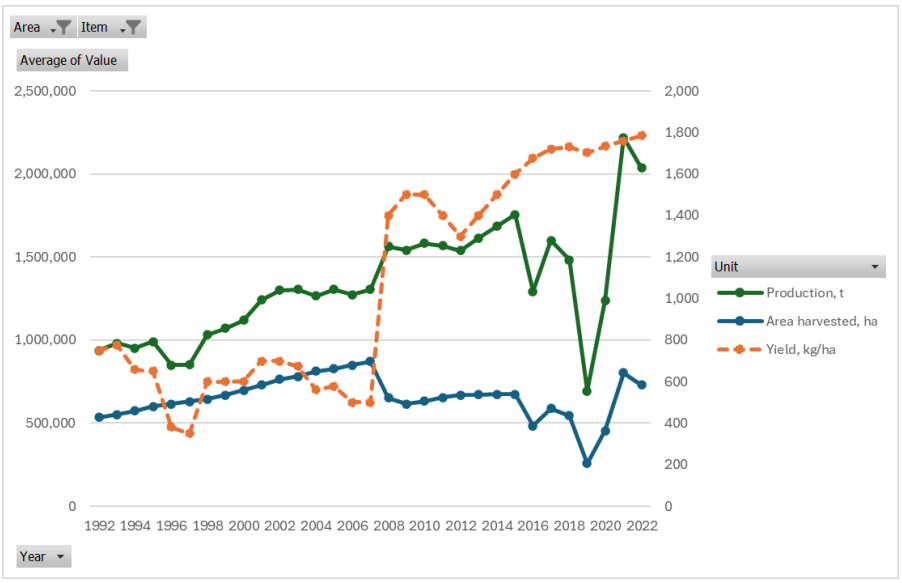

Figure 5-5 Dry beans in Uganda: harvested areas and yields, 1992-2022 (FAOSTAT, 2022)

The bean value chain encompasses input suppliers, producers, village assemblers/middlemen, traders, processors, and consumers. Approximately 69% of beans produced are sold to village collectors and brokers, with 5% going to institutional buyers such as schools and the World Food Programme (WFP). The remaining 26% is kept for home consumption and seed. Village collectors subsequently sell all their beans to traders, including major traders in significant trading centres. These traders then transport the beans to mass markets, institutional buyers, urban traders, or exporters. Urban traders may further sell to institutions or export to countries such as Kenya, South Sudan, Rwanda, DRC, and Burundi (FAO, WFP and IFAD, 2019).

There are a limited number of bean processors in Uganda, who utilize approximately 1% of the total dry beans for producing bean flour. The majority of producers rely on farming as their primary livelihood, with their families constituting the main labour force at this stage (FAO, WFP and IFAD, 2019).

Traditionally in Uganda, men **typically handle ploughing, while women and children are primarily responsible for planting, weeding, harvesting, transportation, threshing, winnowing, and on-farm storage tasks.** Men may occasionally participate in weeding, harvesting, and transportation as hired labourers. In management-related activities, both genders are equally

involved. Marketing activities are predominantly carried out by men, whereas women typically sell small quantities of beans in local markets to earn income for household expenses (Michael Ugen Adrogu, 2017).

The main stages in the bean value chain include primary production, harvesting, transportation of beanstalks to households, threshing and winnowing, drying of bean grains, on-farm storage, and sales by producers. Off-farm stages of the value chain involve trading by bulkers, wholesalers, retailers, and consumption in households (FAO, WFP and IFAD, 2019). Farmers and bean grain aggregators value common beans highly for income generation, while transporters and input dealers see them as moderately valuable. All actors involved rank beans highly in terms of consumption.

Farmers assess bean maturity based on several factors: when most beanstalks have dried and lost their leaves, the pods turn from green to brown and produce a rattling sound when shaken. However, in practice, farmers often delay harvesting until the beanstalks are very dry to minimize grain rotting before threshing and to ease the threshing process. Harvesting is predominantly carried out by household labour, mainly women and children. Hired labour is employed for farms larger than 1 acre. Manual hand harvesting is the most common method in Uganda, particularly suitable for small-scale production, involving uprooting the bean plants from the soil. This process typically requires 6-10 people per acre per day ((FAO, WFP and IFAD, 2019).

After harvesting, beans are bundled and transported to the homestead using methods such as carrying on the head, bicycles, motorcycles, or vehicles, especially for farmers with larger farms exceeding one acre. For those with substantial land holdings, like 4 to 5 acres, hired vehicles such as 2-tonne diesel dumpers are utilized. Typically, women and children carry the crop on their heads, while men use bicycles. Hired labour is also engaged in this process (FAO, WFP and IFAD, 2019).

The un-threshed beans are initially piled on open surfaces like tarps or verandas, typically for a short period of 2 to 4 days until the remaining leaves easily detach during drying. Threshing is performed using sticks, with bean pods spread on the ground, stabilized drying yards, or tarps. After threshing, the beans are manually winnowed, primarily by women using small winnowers. The grains are then dried on surfaces such as tarps, bare ground, mats, concrete, or rocks. Household members assess readiness for bagging through various methods: biting to test hardness, shaking to listen for sound, feeling for dryness, observing colour change, breaking to check cotyledon hardness, or running hands through the beans in sacks. Drying activities predominantly involve household labour, typically performed by women and children (FAO, WFP and IFAD, 2019).

Storage solutions include on-farm and community storage structures. For the on-farm storage, farmers generally put beans in polyethylene bags and store them in their houses. Rural bulkers, located in townships, usually operate 30-tonne capacity stores and handle up to 20 bags of beans per day, sourced from farmers (70%) or agents (30%). They store grain for up to six months, occasionally re-drying it if kept for long periods. Despite this, they maintain a high turnover, selling grain quickly. The bulkers, most commonly men, hire both men and women for re-drying tasks. Quality checks at purchase are minimal, involving biting the grain to check moisture content and assessing cleanliness. Grain with excessive stones, sand, or dust is rejected until the farmer cleans it sufficiently (FAO, 2019).

The primary selling periods are from June/July to August and September to October, with the latter being the peak season for sales. Due to pest challenges and immediate financial needs, farmers usually sell a large portion of their beans within three months of harvest. They commonly sell their produce to other farmers at village markets situated in trading centres, as well as to agents/aggregators and bulk buyers. Farmers also purchase beans from other farmers or retailers at these trading centres to supplement household food supplies (FAO, 2019).

Beans can also be milled to produce value-added products such as bean-based flours, cookies, and snacks. Under new technologies and innovations, certain bean varieties are pre-cooked at high temperatures and pressure, resulting in dry processed pre-cooked beans. These pre-cooked beans are packaged in weather-proof materials such as aluminium sachets, plastic containers, and bags of various sizes for sale to consumers. This product has a shelf life of up to six months (the National Agricultural Advisory Services of Uganda (NAADS), 2024).

Smallholder farmers in Uganda face significant post-harvest losses of beans due to inadequate post-harvest handling practices. Farmers often lack access to information on suitable technologies for post-harvest handling, including quality standards and equipment. Additionally, they struggle to access essential post-harvest services such as drying, threshing, and cleaning beans, primarily due to financial constraints that prevent them from investing in improved post-harvest handling technologies. Consequently, farmers continue to rely on traditional methods such as threshing beans with sticks, which leads to grain breakage, and using local winnowers for cleaning beans (Commercial Agriculture for Smallholders and Agribusiness, 2020).

Inadequate post-harvest handling practices frequently result in compromised produce quality, including high levels of mycotoxin contamination due to fungal attacks, which remains a major concern in the sector. This situation often leads to lower sales prices and diminished nutritional value for farming households. Additionally, poor storage practices at the farm level persist as a common issue. Smallholder farmers continue to underutilize effective storage techniques aimed at preserving crop quality from the farm to processors, retailers, or consumers (Commercial Agriculture for Smallholders and Agribusiness, 2020).

Farmers in Uganda report losing approximately 3.5 kg per 100 kg (3.5%) of their final output during harvesting (FAO, 2019)**.** The primary reasons for these losses include shattering, deliberate handling practices, unharvested beans, and theft. Shattering is the most significant cause, often occurring when beanstalks remain in the field for too long during drying. Deliberate handling practices aimed at maximizing field coverage can also lead to losses, as some pods may break and grains scatter during harvesting, particularly when hired labourers prioritize speed over careful handling. Additionally, unharvested beans rank as the second major cause, typically left behind due to overgrown weeds or careless harvesting. Finally, theft by hired labourers further contributes to losses, as some may steal harvested beans for personal use.

During the transportation of un-threshed beans, farmers estimate losses at 0.71 kg per 100 kg of final output (0.71%). These losses primarily result from theft and transportation difficulties. Theft happens when labourers intentionally drop beans during transit, planning to collect them later for personal use. Additionally, losses occur when beanstalks get tangled in bushes or fall off heaps during transportation from the field. This is often worsened by inadequate transportation infrastructure, such as narrow, overgrown paths, and poorly secured loads (FAO, WFP and IFAD, 2019).

In the next stage of the value chain, on the storage before threshing, farmers reported losses at this stage amounting to 0.09 kg per 100 kg of final output (0.09%). These losses occur when beans spill from the pods onto the ground. Although farmers attempt to salvage some of the grains, there is also a qualitative loss as the beans can become contaminated when they drop onto uncovered ground (FAO, WFP and IFAD, 2019).

During threshing and winnowing, losses were estimated at 0.97 kg per 100 kg of final output (0.97%). These losses primarily result from mechanical damage, spillage, and weather conditions. Mechanical damage is the most significant cause, occurring due to the traditional method of threshing where bean grains are beaten with sticks, leading to some grains being damaged. Spillage happens when grains scatter during the beating process to release them from the pods, and if not gathered

promptly, the farmer loses part of the final yield. Additionally, adverse weather conditions such as excessive wind during winnowing can blow away grains, although farmers mentioned that careful retrieval is feasible (FAO, WFP and IFAD, 2019).

At the next stage, on-farm storage of threshed beans, farmers estimate losses at 1.8 kg per 100 kg of final output (1.8%). These losses mainly stem from spillage, pests and rodents, and mould. Spillage is the most significant cause, often due to the perforation of polyethylene bags used for storage. Pests and rodents contribute to 0.88% of the losses, as farmers typically store beans in their homes to protect against theft and rain, but this environment allows easy access for rodents. Additionally, placing sacks directly on the ground can lead to mould growth, further compromising grain quality (FAO, WFP and IFAD, 2019).

At the last value chain stage, during producer sales, farmers report losses estimated at 3.3%, the highest among their estimates. The main causes include trader manipulation of measuring tools, farmers' use of improper measuring tools, and spillage. The most significant issue is traders manipulating scales, as many small-scale farmers cannot afford their scales and must rely on those provided by traders. These scales are often adjusted to display a lower weight, leading to financial losses for the farmers, although it does not directly affect the value chain. Furthermore, farmers using improvised measuring tools such as basins and containers can inaccurately gauge the weight of beans being sold, resulting in monetary losses of approximately 1.10%. Lastly, spillage, about 0.88 kg per 100 kg of final output, occurs when beans spill out of containers and perforated sacks (FAO, WFP and IFAD, 2019).

The major causes of food losses in the beans value chain in Uganda include inappropriate harvest and post-harvest techniques and practice, as well as poor storage techniques. The summary of the average food loss in the beans value chain in Uganda are presented in the

Table 5-4 below:

Table 5-4 Estimated beans losses in Uganda

Activity	Food supply stage	Average losses, %	Minimum losses, %	Maximum losses, %
Harvesting	Harvest	3.40	3.20	3.60
Shelling, winnowing	Farm	2.54	0.97	4.10
Drying	Farm	1.80	1.80	1.80
Storage	Farm	5.15	1.80	8.50
Storage, trading	Traders/aggregators	3.00	3.00	3.00
Transportation	Traders/aggregators	0.71	0.71	0.71
Wholesale	Traders/aggregators	5.15	0.50	9.80
Bulking, distribution	Traders/aggregators	1.00	1.00	1.00
Retailing	Retail	3.50	3.50	3.50
Consumption	Households	2.50	2.50	2.50

Source: (FAO, 2019), summarized by the author

As we can see, the most critical post-harvest loss points for the beans value chain in Uganda include harvesting, storage, wholesale, and retail. A general overview of the beans value chain in Uganda, covering key stages, processes, stakeholders, climate data, and potential solutions to reduce food losses are presented in the Table 5-5.

Table 5-5 Overview of dry beans food losses in Uganda in the different steps in the value chain, relevant parameters, and suggested solutions

FSC Stage/ process	Processes	% losses (FAO, 2019)	Cause of losses	Affected stakeholders	Climate aspects	Suggested solutions
Harvesting						
Harvesting	Bush beans are collected from the field and uprooted as whole plants, or the single pods are collected	3.40%	Immature grains, spillage	Farmers	Heat stress for workers/farmers and animals, increased humidity/ moisture Rains, winds	Capacity building training on harvesting techniques and harvesting tools Capacity building on drying
Shelling	Manual or mechanical shelling, using manual and mechanical shellers	2.54%	Mechanical damage	Farmers	Rains, winds, temperature	Capacity building on shelling technique, or using mechanical shellers
Winnowing	Separating the edible seeds from the chaff and other debris		Spillage	Farmers	Winds, rains	
Transport from the field	In bulk, using different types of available transport	0.71%	Spillage, mechanical damage	Farmers	Rains, winds	Using trucks and other types of vehicles
Post harvest processes (on-farm)						
Drying	Drying of the threshed beans using tarpaulins, dryers, and similar solutions	1.80%	Insects, rodents, contamination	Farmers	Rains, winds, temperature	
Packing, grading	Sorting, pre-cleaning and packaging		Spillage	Farmers		
On-farm storage	Storage in bags, silos, or baskets	5.15%	Humidity/ mould, insects, rodents	Farmers	Heat/ high temperatures; rains/floods, humidity	Metal and plastic silos, sheds, plastic and hermetic bags, baskets and cribs, solid brick bins, Insecticides/ fumigation
Transport, logistics, further processing						
Collection from farm	Aggregating, transportation to collection centres/ aggregation depot using vans and trucks of various capacity		Spillage	Aggregators/ collectors and traders		

FSC Stage/ process	Processes	% losses (FAO, 2019)	Cause of losses	Affected stakeholders	Climate aspects	Suggested solutions
Storage	In bags	3.00%	Spillage, mould, pests and rodents	Storage companies, warehouses		Storage sheds/structures, insecticides/ fumigation
Wholesale	Packaging, transportation to the sale points (markets, supermarkets)	5.15%	Spillage, mould, pests and rodents	Traders		
Retail	Sales of beans and their products in small and big markets and supermarkets	3.50%	Spillage, mould, pests	Retailers		
Household consumption		2.50%	Spillage	Consumers		

5.2 SHORT-LIST OF FL-RS BASED ON RESULTS OF CLIMATE ANALYSIS

This sub-chapter provides an overview of the most suitable physical and non-physical food loss reduction solutions for Uganda. RE-GAIN Programme aims to increase awareness of smallholder farmers in Uganda regarding the proper utilization of those key FL-RS. Its objectives include ensuring the correct handling and maintenance of these solutions and achieving the maximum reduction of food losses across targeted value chains. This initiative will be executed through a range of capacity-building efforts, including training sessions and the provision of educational materials. The training will be implemented through two primary methods: direct training for smallholder farmers and a "training of trainers" approach. The latter involves capacity-building activities aimed at community focal points, who, upon completion of their training, will facilitate the transfer of knowledge to their communities, encompassing men, women, and youth. Specific proposed activities for Uganda are described in Subchapter 5.2.1.

Besides the soft FL-RS, subchapters from 5.2.2 to 5.2.12 provide evaluation of the different types of physical FL-RS, their quantitative impact on postharvest food loss reduction, and summarizes technical and implementation feasibility, and existing bottlenecks/barriers of those FL-RS in Uganda. The proposed FL-RS in those subchapters have been short-listed considering the specific context of Uganda as well as the overarching project goal, objectives and elements of RE-GAIN programme in sections 5.3 and 5.4.

5.2.1 Awareness raising and capacity building

To ensure the successful adoption of FL-RS and overcome the knowledge barriers that hinder their demand, usage, and maintenance, the RE-GAIN program will incorporate non-physical interventions aimed at raising awareness and strengthening capacity building amongst smallholder farmers. These efforts will focus on key areas, including the effects of climate change on harvesting and post-harvesting processes, the correct use of FL-RS, and proper maintenance practices to maximize the reduction of avoidable food losses within targeted value chains and fostering strong market linkages. This extension service initiative will be executed through a range of a comprehensive range of capacity-building activities, such as hands-on training and educational resources. Two primary methods will be employed to deliver this training: direct instruction to smallholder farmers and a "training of trainers" model. In the latter approach, community focal points will undergo in-depth capacity-building activities. Upon completing their training, these focal points will be equipped to share their knowledge with their communities, ensuring the inclusion of men, women, and youth in the transfer of critical skills and information.

These extension activities have different target audiences: smallholder farmers and production aggregators (or traders) and food processors. For smallholder farmers, raising awareness about critical issues such as food losses, quality, moisture content, aflatoxin contamination, pests, and proper storage methods is essential. Understanding the linkage of these food losses with climate change's impact is also key, raining awareness of the need for farmers to better understand how different agricultural processes, such as timing of harvesting, use of weather forecast data (for timing of harvesting and drying), and appropriate harvesting methods need to evolve to account for the higher variability farmers will encounter with the changing climate.

Environmental and safety aspects, such as the safe use of storage protectants, the safe way of operating different machinery, and correct disposal of the physical solutions, are also part of the training curriculum. Next to the technical aspects of the physical solutions, farmers also need to be trained on the proper use and maintenance of some of those FL-RS such as moisture meters, drying methods, and storage techniques such as hermetic bags, and silos, cleanliness and product quality

management to ensure a long-term usage and sustainability of these solutions. Finally, farmers must also be aware of how they can access finance to invest in FL-RS, and farm business management such as quality management, record keeping, and marketing (for generating revenue to repay loans).

For traders and processors, the focus of the capacity building and awareness raising activities will be on transport logistics, packaging, adherence to quality standards, and the use of storage protectants. Emphasis on value addition through whole grain processing and effective marketing strategies can enhance the profitability and sustainability of their operations.

The indicative extension activities include awareness raising, and capacity building programme is outlined in Table 5-6.

Table 5-6 - Indicative Awareness Raising and Capacity Building elements of RE-GAIN Programme in Uganda

	Awareness Raising	Capacity building
Objectives:	To increase awareness and understanding of post-harvest food losses and the impact of climate change among farmers, stakeholders, and the general public, with the aim of reducing these losses through education, technology adoption, and active involvement of all key stakeholders.	To educate smallholder farmers on improved climate smart crop management and storage techniques and use of available climate information for reducing food losses and to maintain quality of produce, increase farmers' income by reducing losses and improving marketability, and improve supply of financial services and FL-RS to smallholders and other value chain actors
Target Audience	Smallholder farmers, agricultural extension workers, (local) government officials, NGOs and agricultural organizations, agro-dealers, other stakeholders, and the general public	
Key topics and modules	1. **RE-GAIN programme** and its objectives to reduce food losses and for climate change adaptation. 2. **Impact of post-harvest losses on food security**, income, economy, and the environment (incl. climate change) and the importance to reduce FL. 3. **Causes of PH-FL and best practices and improved technologies and methods** (e.g., timing of harvesting, methods and technologies for harvesting, storage, etc.) to reduce in post-harvest losses and their benefits (food security, income environment). 4. Role of different actors (local government, extension services, farmer organisations, agro-dealers, financial institutions) to provide access for FL-RS. 5. **Cross-cutting themes**: climate change awareness, climate smart agriculture, farm management, marketing, product quality management, access to finance, gender and youths, etc.	**1. For all groups of stakeholders:** Introduction to the REGAIN programme, climate change, PH food losses, causes, overview of solutions, providers of solutions, financial literacy and access to credit, product quality, farm records, food security, marketing and aggregation. Gender, youths, food security, environmental aspects and climate change. **2. Training of trainers for extension workers, agro-dealers** Introduction to the RE-GAIN programme, overview of PH losses, climate change and use of available climate information for harvest and post-harvest decision making, causes, priority solutions, providers of loss reduction solutions, setup of trainings and demonstrations, use of promotion materials, advise to smallholders, etc. **3. Trainings for smallholder farmers:** • Identification of the optimal timing of harvesting • Use of available weather forecast information. • Appropriate harvesting methods. • Key reasons of food losses during harvesting and post-harvest management and storage. • Major impacts of climate change on agriculture and postharvest management. • Technical approaches on maintaining crop quality during harvesting, post-harvest handling and storage. • Approaches to measuring and keeping optimal moisture content in crops to prevent aflatoxin contamination. • Approaches and solutions to prevent pest attacks, and proper storage methods. • Best harvesting methods and tools, including mechanization to reduce food losses. • Proper use and maintenance of physical FL-RS, including operation and maintenance of machinery, and their environmental and safety aspects. • Record-keeping, financial literacy and access to finance. Packaging and marketing of crops. • Methods and materials for proper on-farm storage, safe and proper use of pesticides and fungicides, pre-storage crop treatment and preparations, and monitoring storage losses and quality of crops during storage

	Awareness Raising	Capacity building
		• Facilitate linkages between small holders and market actors **4. Training for agricultural traders and processors:** Proper package materials and methods, quality control, proper transport / aggregation methods and systems. Climate change and PH food losses at the trade and processing stages, their causes and solutions, quality management and adherence to quality standards, transport logistics and packaging, sustainable use of storage protectants and storage, processing (including whole grain processing), value addition, supplier management, effective marketing strategies, access to finance. **5. Training for FI-RS providers (manufacturers, importers, agrodealers)** Proper service management, safe, effective, efficient and sustainable operation of the equipment and provision of the services. **6. Institutional capacity building** Enhancing the capacities of extension services, meteorological services, monitoring of FL, FL reductions and opportunities for upscaling and replication. Capacities for value chain and market networking.
Activities	• Mass media campaigns: radio, television, digital platforms and social media. • Collaboration with local governments and farmer organisations. • Monitoring outreach and impact.	**For smallholders:** • Information/training meetings at district and community level • Demonstrations, using e.g. the "mother-baby" approach practiced by VBAs in other AGRA programmes, • Exchange visits. **For providers of FL-RS and institutional target groups:** • training seminars/workshops • exchange visits.
Materials	**For smallholder farmers:** • Training and capacity building (including advisory services) organized through the network of village-based advisors (VBAs), complemented by extension workers and NGOS (where necessary) • Educational materials • Demonstration materials • Training of trainers **For traders, processors, FL-RS manufacturers and suppliers/ importers/ agrodealers** • Printed and online materials • Trainings and seminars	

To ensure the most effective introduction of the physical FL-RS, RE-GAIN programme envisions the launch of capacity building and awareness raising activities already in the first year of its implementation. This will create the awareness about the project across country and the target stakeholders and ensure that smallholder farmers are aware and capable of utilizing the provided physical FL-RS in the most effective and suitable way.

Development of education materials will be implemented by AGRA national teams involved in the project, based on the most crucial topics identified for Uganda, and considering those shortlisted FL-RS identified as priority.

Training of trainers for farmers, and trainings and seminars for the traders, processors, FL-RS manufacturers and agrodealers will be conducted in two stages: curriculum development by AGRA staff and actual training sessions delivered by AGRA in collaboration with the VBAs.

Effective financial mechanisms are essential for enhancing access to food loss reduction solutions in all seven countries. They are of particular importance for smallholder farmers, struggling with the lack of financial resources and barriers to access finance, that are needed for investment into the improved postharvest management technologies and tools. Delivery

of the physical FL-RS through the selected financial mechanisms to farmers and other target stakeholders will be implemented starting from the 2nd year of the Programme.

Monitoring of the outreach, effect and impact of the awareness raising, and the training and capacity building and adaptation of FL-RS is essential to document project progress, but also as management information to adjust the project activities to achieve the desired effect and impact. The monitoring should specifically identify possible barriers that smallholders and other stakeholders might experience, to timely identify project constraints and to make adjustments for overcoming these barriers. Another aspect will be the monitoring of the technical aspects of quality and impact of the demonstrations including the cost effectiveness. The outreach of local awareness activities and local capacity building will help to create a network for information feedback from project stakeholders that can be used for monitoring purposes. The described activities will be aligned with the country stakeholder engagement plans, and the general monitoring and evaluation (M&E) of RE-GAIN programme.

5.2.2 Wholegrain processing

Besides the capacity building and awareness raising on those key FL-RS, it is also important to consider **additional measures to prevent postharvest losses, such as for example value added (whole grain) processing.** Wholegrain processing offers substantial benefits in mitigating food losses, which is a critical concern in contemporary food systems in RE-GAIN's target countries. Wholegrains, encompassing the bran, germ, and endosperm, retain more nutrients compared to refined grains, which undergo significant nutrient removal during processing.

Wholegrain processing optimizes the use of the entire grain, ensuring that fewer resources are wasted during milling and production. This comprehensive utilization aligns with sustainable food production practices, reducing the environmental impact associated with food loss and waste. Wholegrain processing is applicable to key staple crops such as maize, wheat, and rice. The integration of wholegrain processing in food systems also promotes health benefits due to the higher fibre content and essential nutrients retained, which can improve public health outcomes and reduce healthcare-related food wastage.

Raising awareness about the benefits of wholegrain processing will be an important part of the Component 1 of the RE-GAIN programme in Uganda, as it belongs to both adaptation of existing food loss technologies to climate change, and awareness raising activities of the Programme. It will respond to the existing barriers to the increased adoption of wholegrain processing, such as urbanization and related low availability of wholegrain processing, shorter shelf life of wholegrain products, and consumer preferences for processed white flour as a prestige, premium product. Raising awareness about the benefits of wholegrain processing will assist in changing consumers' mindset about wholegrain flour towards their better understanding of the nutritional values of wholegrain products and its importance in ensuring food security in Uganda.

5.2.3 Physical solutions

In addition to capacity building and awareness raising activities, a package of physical FL-RS is envisaged for each RE-GAIN target country. **During the initial stage of consultations with the AGRA programme development team, several criteria were identified for pre-selecting FL-RS for each target country.** The primary focus was to identify context-specific technologies and practices that exhibit the highest potential to mitigate food losses caused by climate change-driven hazards. This process targeted the seven focus countries and concentrated on the key crops and value chain stages where losses are most prevalent.

The FL-RS shortlisting evaluation criteria included:

a) Unit cost and cost-effectiveness of the solution.
b) Target audience, distinguishing between agricultural cooperatives and individual farmers.
c) Accessibility of the solution, including available supply, location of target farmers and suppliers.
d) Estimated reduction in food losses/ Positive impact of the FL-RS.
e) Possibility of using the solution for different crops, and
f) Technical and implementation feasibility, and existing bottlenecks/barriers.

The general FL-RS evaluation matrix is presented in Figure 5-6 below.

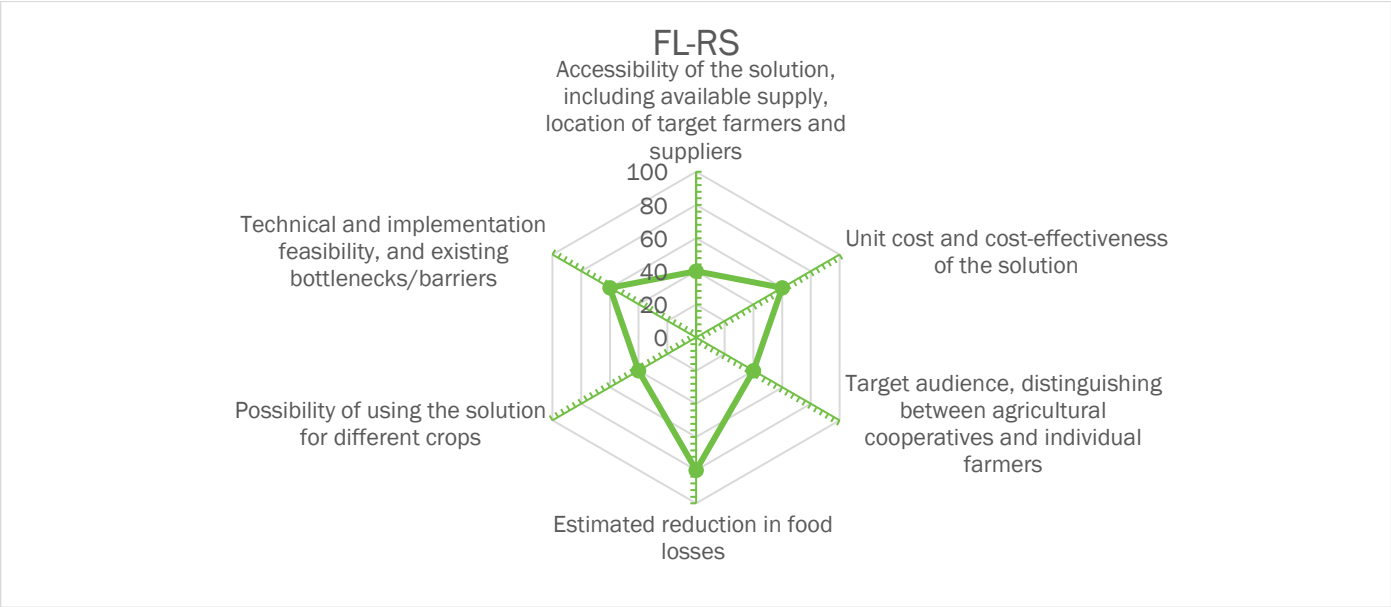

Figure 5-6 - FL-RS evaluation matrix

Based on the results of the analysis provided in the previous sections for the baseline study, 10 key physical FL-RS were identified, including:

- Harvesting machinery (e.g., multi-crop harvesters)
- Mechanical multi-crop threshers and shellers
- Tarpaulins and plastic sheets
- Wooden and metal cribs
- Metal and plastic silos
- Hermetic and other plastic bags
- Moisture meters
- Storage structures (e.g., huts, baskets, grain sheds)
- Storage protectants and control agents (biological fumigants, insecticides and pesticides)
- Transport packaging (e.g., wooden crates and bags)

Postharvest food loss reduction volumes, together with the specific evaluation of each FL-RS and other critical points per each solution are provided below.

5.2.3.1 Harvesting machinery

Integration of harvesting machinery (including multi-crop harvesters) into the harvesting processes has demonstrably reduced food losses during the harvest period. Empirical studies indicate that the efficiency of mechanical harvesters, such as combine harvesters, leads to substantial conservation of crops that would otherwise be lost through traditional manual harvesting techniques (Hasan M. &., 2020). For instance, mechanized rice harvesters have been shown to reduce grain loss from the typical 10-15% observed in manual harvesting to as low as 2-5% (Muhammad Yasin, 2019). Similarly, the use of corn harvesters optimizes the timing and condition of harvest, enhancing yields by 20-30% compared to manual methods (Mutungi, 2023).

Mechanized harvesting systems have also proven effective in reducing losses in various other crops, such as wheat and beans. For example, wheat harvesters can decrease losses by ensuring precision in cutting, threshing, and cleaning, thus saving between 5-10% of the total harvest (Aparna Kumari, 2023). Multi-crop harvesters, which are adaptable for various crops, have significantly reduced grain losses by efficiently managing multiple hectares per day with minimal resources (Mathanker S. H., 2014). These machines not only improve the quantity of harvest saved but also enhance the quality, resulting in higher market value and profitability for farmers.

The evaluation of harvesting machinery is provided in Figure 5-7.

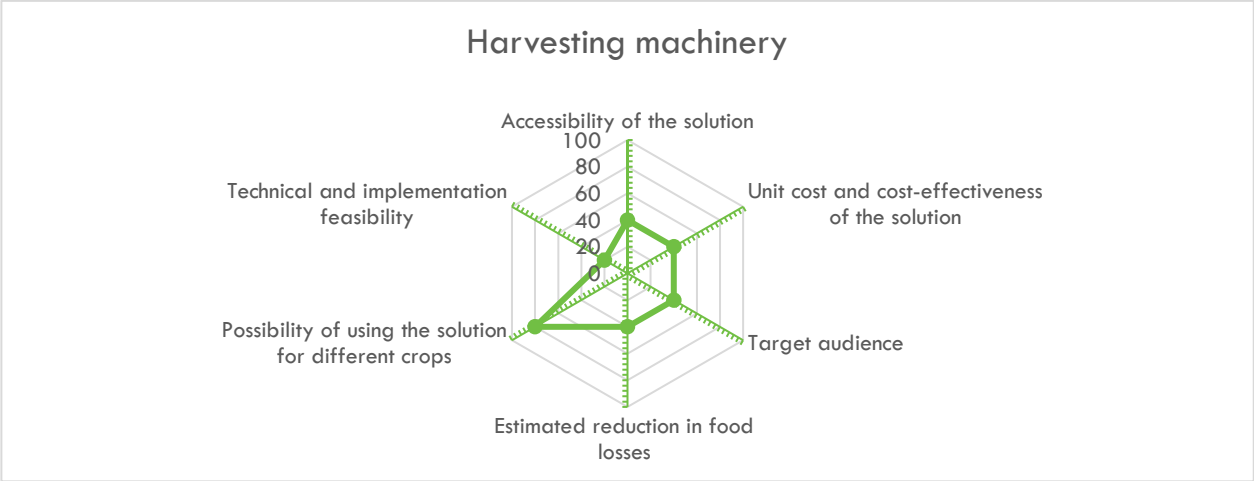

Figure 5-7 - FL-RS evaluation for harvesting machinery

5.2.3.2 Mechanical multi-crop threshers and shellers

Proper utilization of mechanical multi-crop threshers and shellers has the potential to significantly enhance the efficiency and effectiveness of post-harvest processing, leading to substantial savings in the harvest (Amponsah S. &., 2017). The exact amount of harvest saved varies based on factors such as the type of crop, the machine's efficiency, and the traditional methods being replaced. However, in comparison to traditional manual methods that often result in higher losses due to incomplete threshing, spillage, and grain breakage, proper and timely threshing of crops such as maize and soybeans using mechanical devices can reduce these losses significantly, typically by 10-20% (Amponsah S. &., 2017) and up to 25-30% (FarmBiz Africa, 2020). Besides that, using more environmentally friendly machinery, such as solar-powered portable threshers and shellers is beneficial for farmers from two points: they reduce air pollution, and allow farmers to save money, as solar-powered machinery does not require fuel, that is costly in many cases.

Additional benefits of mechanical threshers and shellers include their ability to process larger volumes of crops in a shorter time compared to manual methods, aiding in timely processing and reducing the risk of losses due to delays such as weather damage or pest infestations. Besides that, machines generally handle crops more gently and uniformly, resulting in fewer damaged grains, which can enhance the market value of the produce. There are also significant labour and related financial savings associated with mechanical threshers and shellers (Getachew M. &., 2022). The reduced need for manual labour is particularly beneficial during peak harvest times when labour shortages are common, leading to cost savings and ensuring timely processing of the harvest.

Across Sub-Saharan Africa, the Soybean Innovation Lab (SIL) developed multi-crop threshers that have shown remarkable results, reducing post-harvest losses to less than 2% compared to up to 30% with traditional methods (Soybean Innovation Lab, 2016). SIL threshers can process crops up to 80% faster than manual methods, requiring only two operators, thus saving time and reducing labour costs significantly (Soybean Innovation Lab, 2016).

Despite the benefits of the multi-crop threshers and shellers, there are also challenges to consider (Trans-Sec, 2013). The initial investment in mechanical threshers and shellers can be high for smallholder farmers (Getachew M. &., 2022), though the long-term benefits of reduced losses and increased efficiency often outweigh these costs. Proper training for operators and regular maintenance are crucial to ensure the optimal performance of these machines (Getachew M. &., 2022). Without technical know-how, there is a risk of underutilization or breakdowns, which can negate the potential benefits.

The evaluation of mechanical multi-crop threshers and shellers is provided in Figure 5-8.

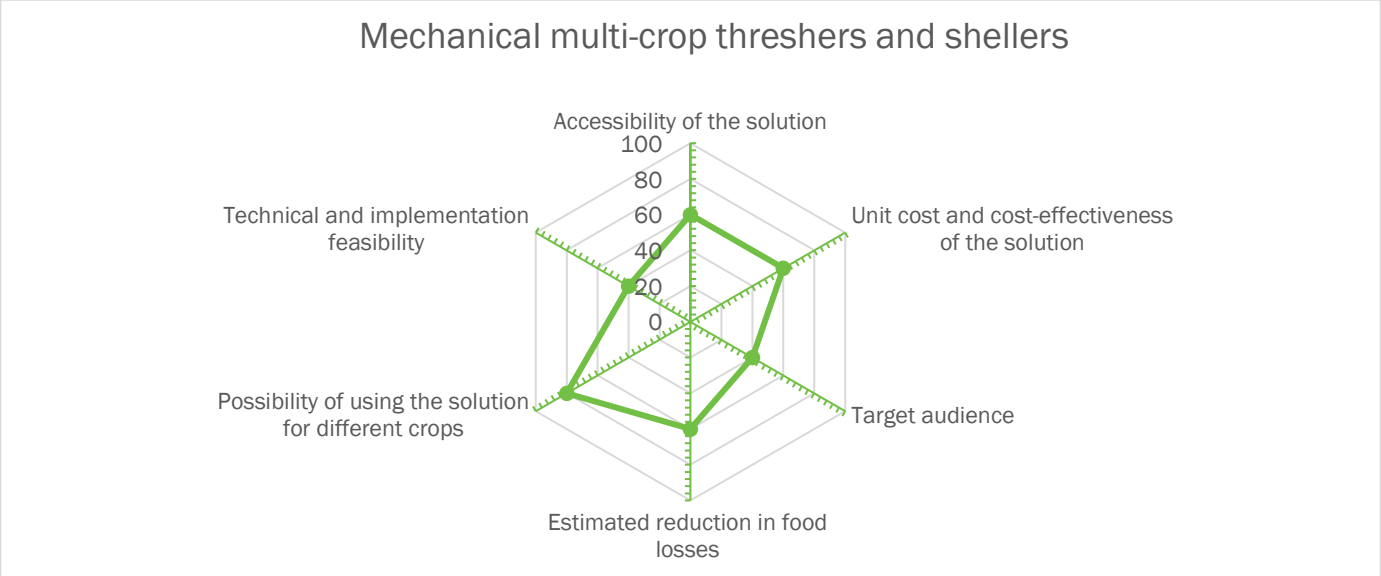

Figure 5-8 - FL-RS evaluation for mechanical multi-crop threshers and shellers

5.2.3.3 Tarpaulins and plastic sheets

Effectiveness and efficiency of using **tarpaulins and plastic sheets** for drying harvested crops such as maize and beans varies depending on the type of crop, local climate conditions, and pre-existing postharvest practices. For instance, in the case of grains and cereals such as rice, maize, and wheat, traditional drying methods often result in postharvest losses ranging from 10% to 30%, primarily due to spillage, spoilage, and contamination. However, the use of tarpaulins and plastic sheets can reduce these losses to between 5% and 10% by providing a clean, controlled drying environment (Hodges R. J., 2011). Legumes and pulses, such as beans and lentils, which traditionally experience losses of 15% to 35%, can see a reduction to

5% to 15% when using improved drying methods with tarpaulins and plastic sheets (Grolleaud, 2002). This is primarily due to better protection from environmental factors and pests.

Various case studies highlight the effectiveness of tarpaulins and plastic sheets for drying. A study from Kenya demonstrated that using plastic sheets for maize drying reduced postharvest losses from 20% to less than 5% (Affognon H. M., 2015). In Nigeria, improved drying methods for cowpeas resulted in a reduction of losses from 25% to around 10% (Opara, 2013).

The benefits of using tarpaulins and plastic sheets for drying are manifold. These materials provide enhanced protection by shielding crops from rain, pests, and soil contamination, thereby ensuring cleaner drying conditions (Kitinoja L. S., 2011). They also improve drying efficiency by enabling faster and more uniform drying, which reduces the risk of mould and spoilage (FAO, 2010). Additionally, tarpaulins and plastic sheets are relatively inexpensive and accessible, making them particularly beneficial for smallholder farmers (Affognon H. M., 2015). The use of these drying methods often results in higher quality produce, which can command better market prices (Kader, 2005).

The evaluation of tarpaulins and plastic sheets is provided in Figure 5-9.

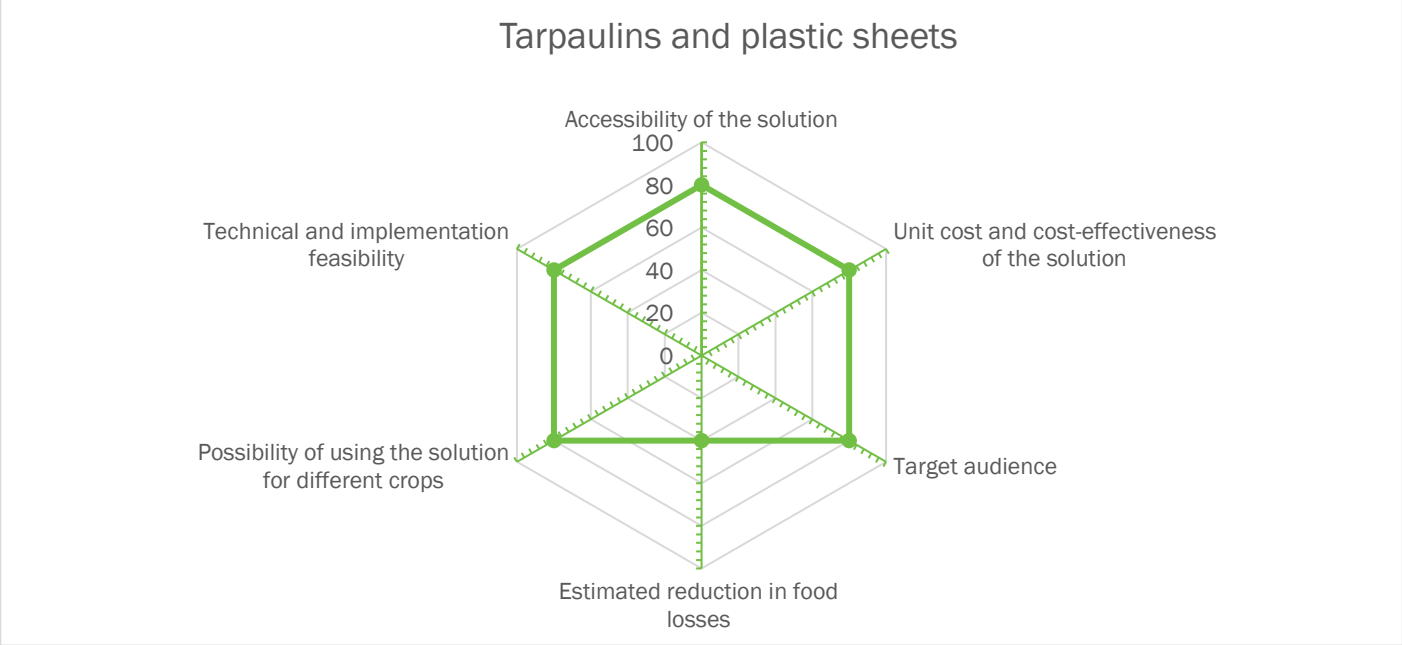

Figure 5-9 - FL-RS evaluation for tarpaulins and plastic sheets

5.2.3.4 Wooden and metal cribs

Appropriate use of wooden and metal cribs for on-farm storage of harvested crop offers can decrease postharvest losses by 30-50%, providing substantial benefits to smallholder farmers in developing regions prone to high losses due to pests, moisture, and physical damage (Julius, 2021). The effectiveness of these storage methods varies with crop type, with cereals like maize and rice benefiting notably (FAO, 2011). In humid regions, the loss reduction efficacy of cribs may be less unless supplemented with additional drying mechanisms. Maintenance is crucial to sustain the cribs' effectiveness over time.

Wooden cribs achieve this loss reduction by enhancing air circulation, aiding in drying and reducing moisture, which curtails fungal and bacterial proliferation. These cribs also offer protection from rodents and insects, and minimize physical damage, potentially reducing postharvest losses by 30-40%, particularly in grains like maize (FAO, 2011). Conversely, metal cribs are noted for their durability and superior sealing against pests and environmental elements such as rain and humidity. Despite

potential heat conduction issues in hot climates, which can be alleviated through proper design, metal cribs can reduce losses by 40-50%, especially in regions with significant pest and weather challenges (Tadele Tefera, 2011).

The evaluation of wooden and metal cribs is provided in Figure 5-10.

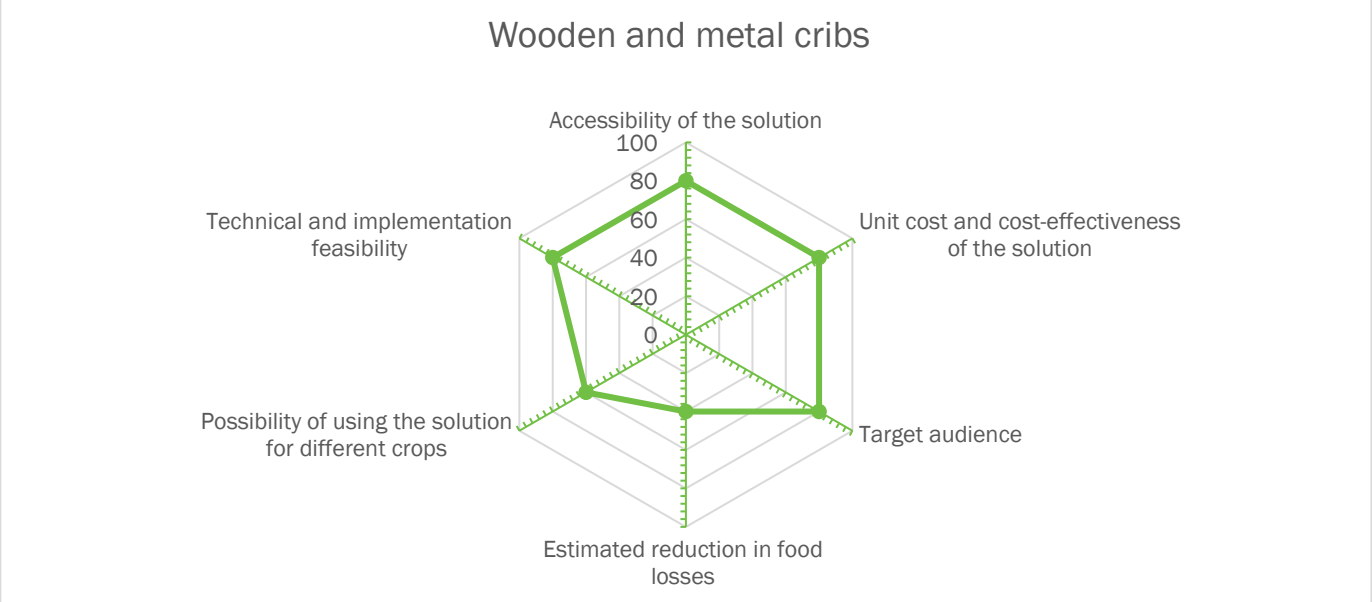

Figure 5-10 - FL-RS evaluation for wooden and metal cribs

5.2.3.5 Metal and plastic silos

The use of metal and plastic silos for grain storage has long been identified as an effective solution to mitigate postharvest food losses, particularly in Africa, as silos offer a hermetically sealed environment, protecting the grains from pests, moisture, and other spoilage factors that are prevalent in traditional storage methods such as bags or earthen pits.

Metal silos, typically made from galvanized steel, provide robust protection against rodents and insects, which are common causes of postharvest losses. Studies have shown that grain stored in metal silos can have losses reduced to less than 1-2% compared to traditional methods which often exceed 10-15% (Njoroge A. W., 2019). This significant reduction in losses translates to increased food security and economic benefits for farmers, who can store their produce for longer periods without quality degradation.

Plastic silos, while not as durable as their metal counterparts, offer a cost-effective alternative that still provides substantial benefits. These silos are typically made from high-density polyethylene (HDPE) and can be locally manufactured, reducing costs and making them accessible to smallholder farmers. In Kenya, the introduction of plastic silos has proven its ability to reduce postharvest losses in small-scale maize farming by up to 50% compared to traditional storage methods (De Groote H. K., 2013). The lightweight nature of plastic silos also makes them easier to transport and install, facilitating their adoption in remote areas.

The economic implications of using these improved storage technologies are profound. Case studies have shown that the adoption of metal silos by smallholder farmers can lead to an average increase in annual household income by approximately 20% (Gitonga Z. M., 2015). This increase is attributed not only to the reduction in postharvest losses but also to the ability to sell stored grain when market prices are higher, thereby optimizing income. While the initial investment in metal and plastic silos can be a barrier for some farmers, the long-term benefits in loss reduction and economic gains make them a worthwhile

investment (Kuyu C. &., 2022). Moreover, the use of silos contributes to environmental sustainability by reducing the need for chemical preservatives, which are often used in traditional storage methods to combat pests and mould (Kuyu C. &., 2022). The hermetic nature of both metal and plastic silos eliminates the need for such chemicals, thereby promoting safer food practices and reducing environmental contamination.

The evaluation of metal and plastic silos is provided in Figure 5-11.

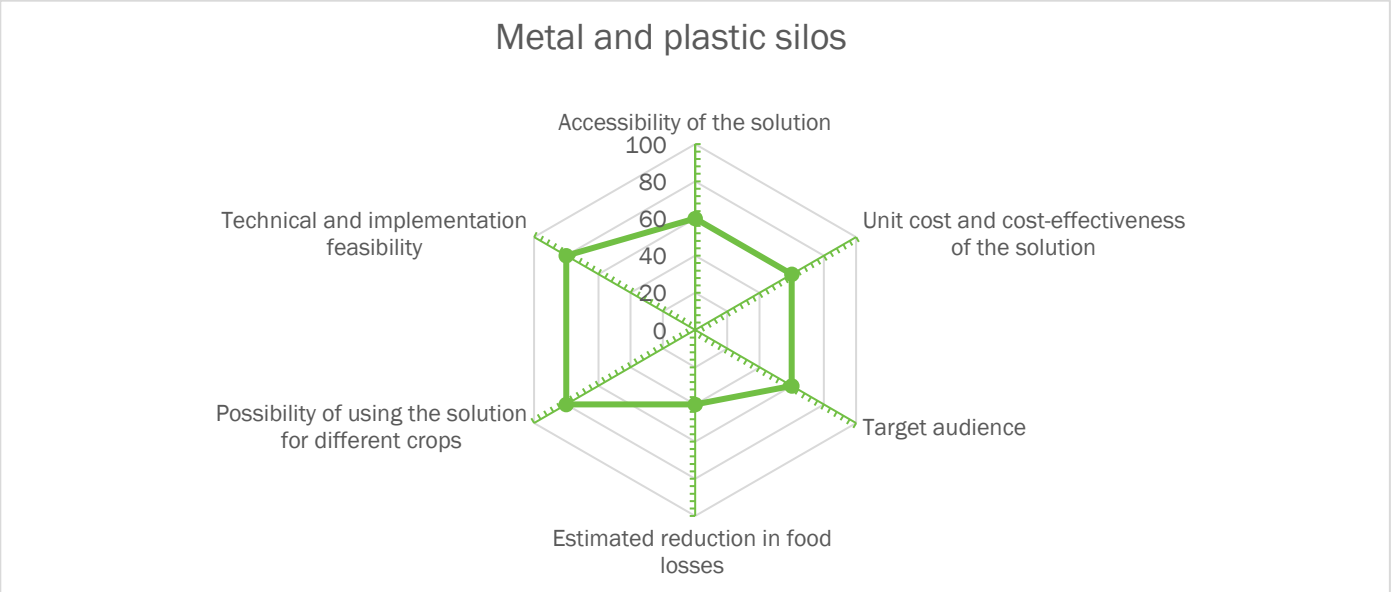

Figure 5-11 - FL-RS evaluation for metal and plastic silos

5.2.3.6 Hermetic bags

Hermetic storage technologies, such as Purdue Improved Crop Storage (PICS) bags and other plastic bags, have shown great promise in mitigating postharvest food losses across various African countries (Williams S. M., 2017). Hermetic storage involves airtight conditions that prevent the entry of oxygen, thereby inhibiting the growth of aerobic organisms like fungi and insects. This method has proven particularly effective for staple crops such as maize, cowpeas, and rice, which are prone to significant postharvest losses (Baributsa D. &., 2020). The benefits of hermetic bag storage extend beyond mere loss reduction; they include improved food security, enhanced grain quality, and increased incomes for farmers (Williams S. M., 2017).

For instance, research conducted by the Purdue Improved Crop Storage project found that PICS bags could reduce grain losses by up to 20% compared to traditional storage methods such as polypropylene bags or open-air storage. Specifically, in a study conducted across multiple countries in Africa, it was observed that the use of PICS bags reduced cowpea storage losses to less than 1%, compared to losses of 20-30% in traditional storage methods (De Groote H. K., 2012).

In Kenya (Koskei P. &., 2020), introduction of PICS bags led to a substantial reduction in maize postharvest losses. In the Rift Valley region, farmers who adopted PICS bags reported a decrease in losses from an average of 25% to below 5% over a six-month storage period (Koskei P. &., 2020). This reduction is significant, considering that maize is a critical staple crop for both consumption and income generation in Kenya. The economic impact of reduced postharvest losses is profound, as it translates to increased food availability and reduced financial losses for farmers (Koskei P. &., 2020).

Despite the initial cost of hermetic bags being higher than traditional storage methods, the long-term economic and food security benefits make them a viable and beneficial investment (Baributsa D. &., 2020). Scaling up the use of hermetic storage solutions could significantly impact the fight against food insecurity in Sub-Saharan Africa, making it a key strategy in postharvest loss reduction efforts. As hermetic storage tools are made of plastics, within the scope of RE-GAIN programme we are looking primarily into the solutions made of recycled plastics. It is also important to consider the existing reuse and recycling approaches used in the target regions and encourage increased collection and recycling of the solutions previously being in use.

The evaluation of hermetic storage bags is provided in Figure 5-12.

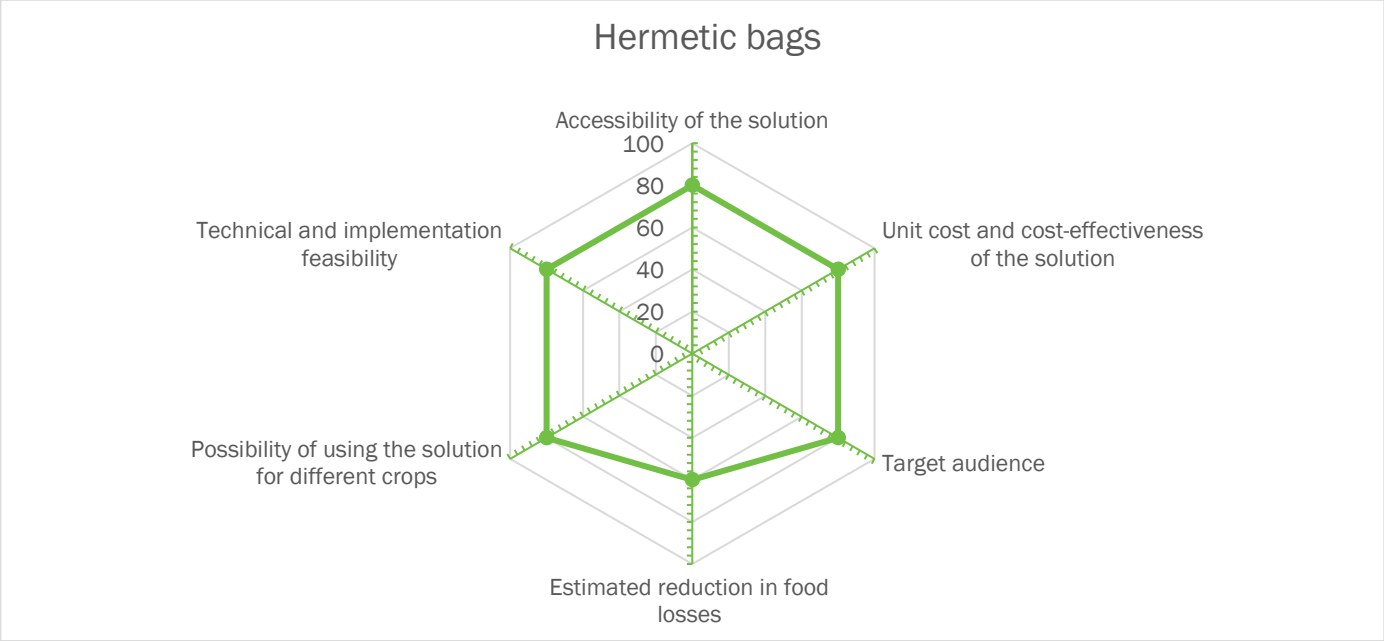

Figure 5-12 - FL-RS evaluation for hermetic bags

5.2.3.7 Moisture meters

Moisture meters over the recent years have emerged as a crucial technology in mitigating postharvest food losses in many African countries, helping to avoid up to 25%of postharvest food losses, and offering a practical solution to preserving the quality and quantity of harvested crops (Hossain M. &., 2016). By accurately measuring the moisture content in grains and other produce, farmers can make informed decisions about the timing and conditions of storage, thereby preventing spoilage and degradation. Through minimizing the risks associated with improper storage, moisture meters help ensure that a greater proportion of the harvested produce reaches consumers in optimal condition, supporting the livelihoods of farmers and contributing to the stability of the food supply chain (Hossain M. &., 2016). Studies show that Kenya has already successfully integrated moisture meters into postharvest management practices for grains, particularly maize, resulting in improved storage and reduced losses (Koskei P. &., 2020).

The evaluation of moisture meters is provided in Figure 5-13.

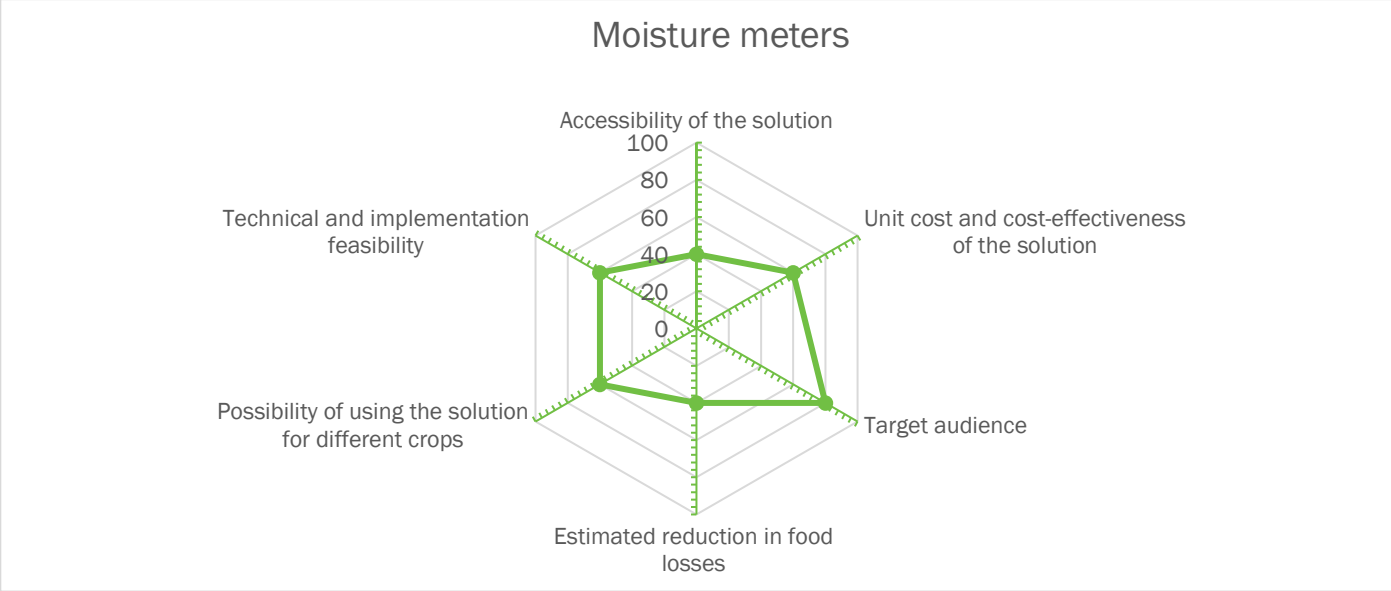

Figure 5-13 - FL-RS evaluation for moisture meters

5.2.3.8 Storage structures

Storage structures (e.g., huts, baskets, grain sheds) when designed and utilized correctly, offer practical and effective solutions to the pervasive problem of postharvest losses in Africa (World Bank, 2011). They provide controlled environments that protect crops from various biotic and abiotic factors that contribute to deterioration. Grain sheds have proven their effectiveness in Africa, by reducing losses from 20% to as low as 5%, achieved through better control of storage environment conditions, such as temperature and humidity (Befikadu, 2014). Moreover, grain sheds facilitate the aggregation of produce, making it easier for farmers to manage and monitor their stored crops, further enhancing loss prevention.

Huts, traditionally used in many African communities, can also be optimized to improve storage outcomes. In regions like West Africa, modifications to traditional storage huts have included elevating the structures to prevent rodent access and incorporating materials like mud plaster or cement to deter insects (FAO, 2014). In Ghana, such improvements in storage huts have led to a reduction in postharvest losses from an estimated 15% to 7%. These huts, when properly maintained, provide a cost-effective and culturally acceptable solution for smallholder farmers to safeguard their harvests (Ansah I. &., 2018).

The evaluation of storage structure is provided in Figure 5-14.

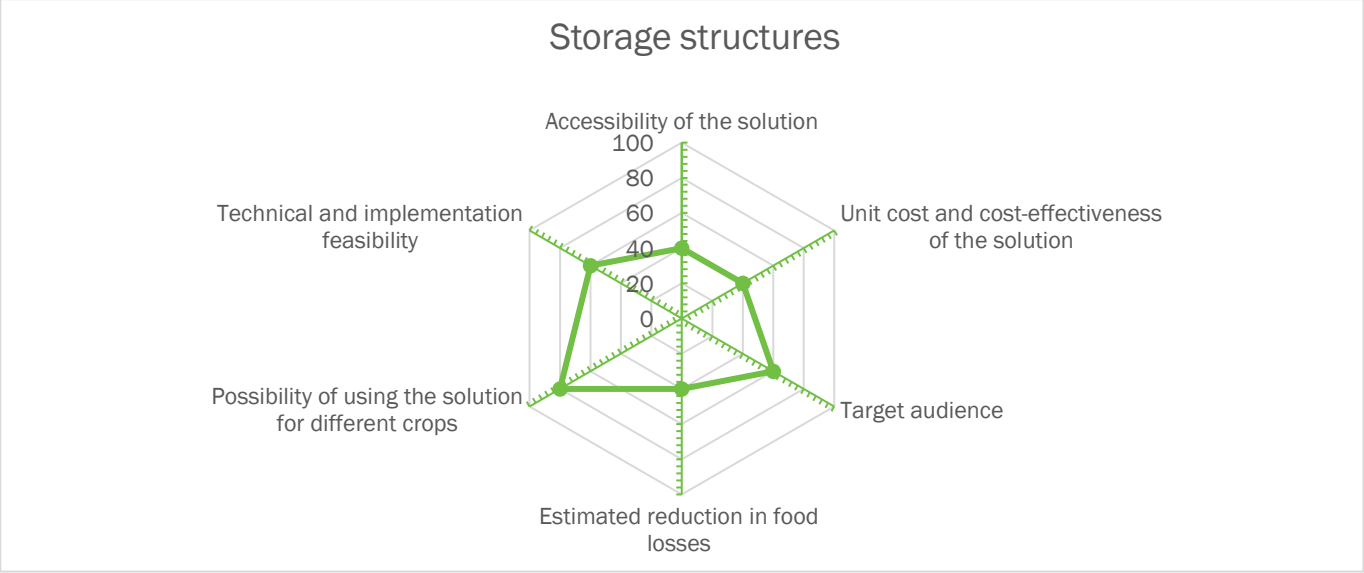

Figure 5-14 - FL-RS evaluation for storage structures

5.2.3.9 Storage protectants and control agents

Storage protectants and control agents (such as fumigants, insecticides and pesticides) are very common and popular solutions for food loss reductions and are widely used by smallholder farmers in Africa due to their affordability and availability (Nukenine, 2010). Insecticides, when judiciously applied, can help to prevent pest damage. For example, a study in Kenya demonstrated that the application of synthetic pyrethroids reduced maize weevil infestation by 35%, consequently lowering postharvest losses by approximately 30% (Tefera T. M., 2011). Pesticides, though controversial due to potential health and environmental impacts, have shown effectiveness in maintaining grain quality (Nukenine, 2010). Research conducted in Ethiopia indicated that the proper use of phosphine fumigation decreased losses in stored wheat by over 40% (Negussie, 2012). As an organic alternative, biological fumigants, including products like Bacillus thuringiensis and diatomaceous earth, provide an eco-friendly approach to pest control, reducing losses by up to 25% in some studies. Plus there remains a considerable need to raise awareness regarding the proper use (dosage and application of chemical protectants) across the countries. Additionally, there is a need to develop the supply of biological protectants and control agents in the markets.

The application of these protectants not only preserves the quantity but also the quality of stored produce, ensuring that grains remain fit for consumption and marketable. This has a direct economic benefit for smallholder farmers, who constitute a significant portion of the agricultural sector in Africa (Obeng-Ofori, 2015). For instance, integration of chemical treatments with improved storage facilities, such as hermetic bags, can lead to a reported reduction in maize postharvest losses by up to 50% (Abass A. B., 2014). However, it is essential to balance the use of chemical protectants with environmental sustainability and health safety considerations, advocating for integrated pest management approaches that combine chemical and non-chemical methods to achieve optimal results. Therefore, within the scope of proposed FL-RS for the RE-GAIN project, our focus will be primarily on the organic/ natural protectants, as well as their combinations with other physical FL-RS.

The evaluation of storage protectants and control agents is provided in Figure 5-15.

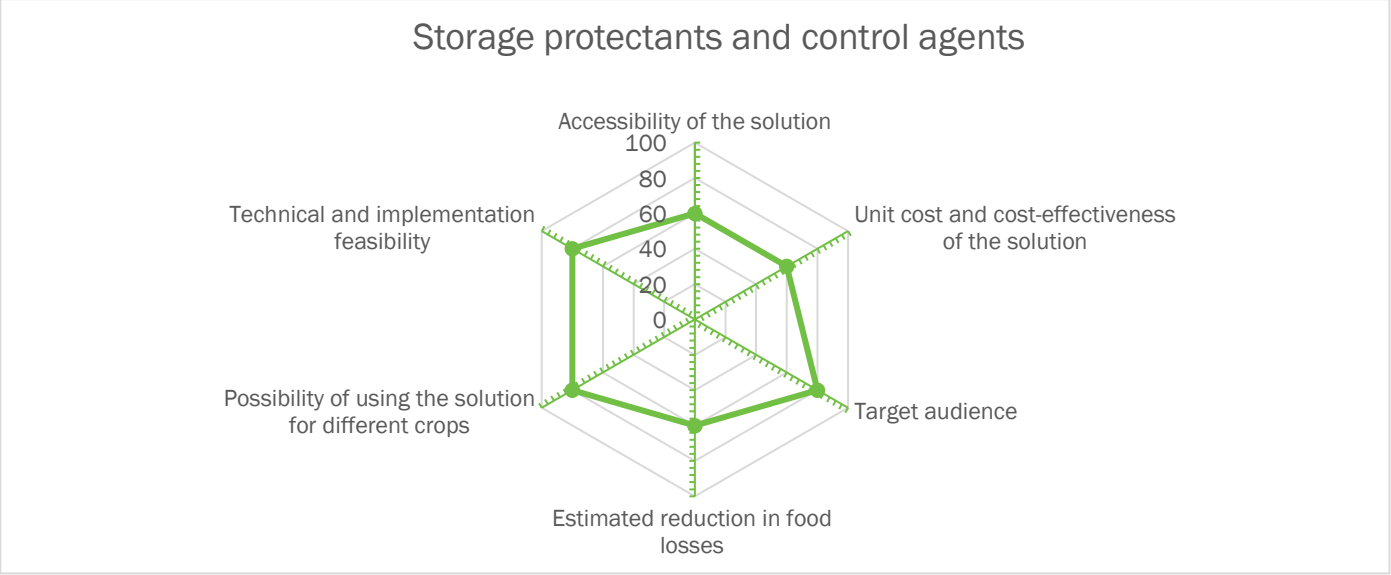

Figure 5-15 - FL-RS evaluation for storage protectants and control agents

5.2.3.10 Transport packaging

Proper transport packaging (e.g., wooden crates and bags) used for the crop's transportation from farm to the market or an aggregation centre, plays a crucial role in preserving the quality and quantity of produce (Kitinoja L. , 2016). It helps to reduce mechanical damage, spillage, contamination, and spoilage, that in some cases might be significant. For instance, research indicates that in Sub-Saharan Africa, postharvest losses can range between 30-50% of total agricultural output, primarily due to poor handling and inadequate packaging (Kitinoja L. S., 2011). Implementing better packaging solutions can reduce these losses by up to 15%, as evidenced by various case studies (Affognon H. M., 2015). For example, use of improved packaging materials for transporting beans cut postharvest losses by nearly half, from 35% to 18% (Adejumo B. &., 2007). But as identified by (AGRIFIN, 2020), farmers rarely have financial capacity and physical access to transport packaging of suitable quality.

The evaluation of transport packaging is provided in Figure 5-16.

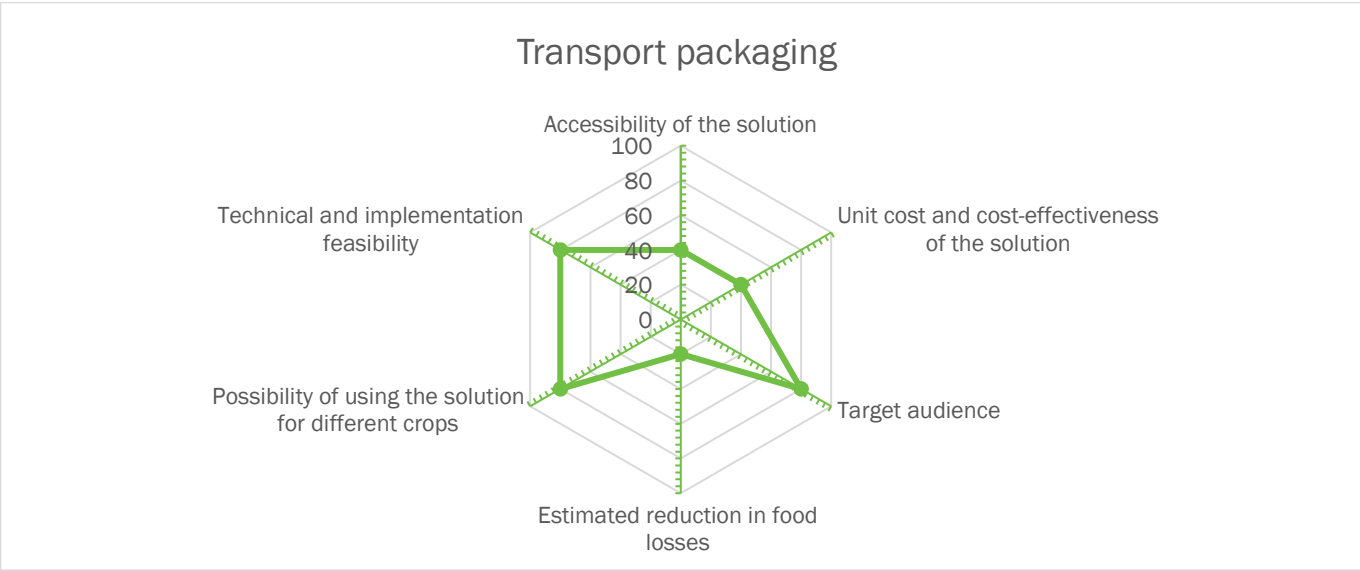

Figure 5-16 - FL-RS evaluation for transport packaging

Summary of the above-mentioned reduction in postharvest losses attributed to those 10 key physical FL-RS are presented in the Table 5-7.

Table 5-7 - Key physical FL-RS and their potential in reducing postharvest losses

Solutions	Estimated reduction in post-harvest losses, %
Harvesting machinery	**10-15%** *Sources:* (Hasan M. &., 2020); (Mutungi, 2023); (Muhammad Yasin, 2019); (Aparna Kumari, 2023); (Mathanker S. H., 2014)
Mechanical multi-crop threshers and shellers	**10-30%** *Sources:* (Amponsah S. &., 2017); (FarmBiz Africa, 2020); (Getachew M. &., 2022); (Soybean Innovation Lab, 2016)
Tarpaulins and plastic sheets	**10-20%** *Sources:* (Hodges R. J., 2011); (Grolleaud, 2002); (Affognon H. M., 2015); (Kitinoja L. S., 2011)
Wooden and metal cribs	**30-50%** *Sources:* (Julius, 2021); (FAO, 2011); (Tadele Tefera, 2011)
Metal and plastic silos	**10-50%** *Sources :* (Njoroge A. W., 2019); (De Groote H. K., 2013)
Hermetic and other plastic bags	**20-30%** *Sources:* (Williams S. M., 2017); (De Groote H. K., 2012); (Koskei P. &., 2020)
Moisture meters	**Up to 25%** *Sources:* (Hossain, Awal, Ali, & Alam, 2016); (Koskei, Bii, Musotsi, & Karanja, 2020)
Storage structures	**Up to 15%** *Sources:* (Befikadu, 2014); (FAO, 2014); (Ansah, Ehwi, & Donkoh, 2018)
Storage protectants and control agents	**30-40%** *Sources:* (Tefera T. M., 2011); (Abass, Ndung'u, & Bekunda, 2014)
Transport packaging	**10-15%** *Sources:* (Affognon, Mutungi, Sanginga, & Borgemeister, 2015); (Adejumo & Raji, 2007)

5.3 DEFINITION OF FEASIBILITY AND PRIORITISATION CRITERIA FOR FL-RS

Based on the evaluation provided in the previous subchapter and the round of national and local stakeholder consultations, three key criteria were shortlisted for the selection of those FL-RS, namely:

- Solutions that respond to the identified climate risks in the value chains of beans and maize
- Solutions that can help with food loss reductions and have the potential to be scalable with smallholder farmers
- Solutions that are appropriate to the local context

5.3.1 Solutions that respond to the identified climate risks in the beans and maize value chains

In terms of climate risks, both maize and beans in Uganda are highly vulnerable to increase in average temperatures and extreme heat and heat waves, as well as heavy rainfalls and floods, as identified in Table 3-9. This vulnerability can lead to

reduced yields, spoilage, mould and aflatoxin development, making right time for harvesting, proper threshing and shelling, and adequate drying and storage facilities crucial in postharvest losses reduction.

An evaluation of the ten shortlisted flood resilience solutions (FL-RS) and their potential to mitigate the impacts of key climate hazards in the beans and maize value chains is presented in Table 5-8 and Table 5-9 below. This evaluation employs a scoring approach, with the following grades: very low mitigation/adaptation impact (1 point), low mitigation/adaptation impact (2 points), medium mitigation/adaptation impact (3 points), high mitigation/adaptation impact (4 points), and very high mitigation/adaptation impact (5 points). The scoring of each solution is derived from research results detailed in previous chapters and outcomes from stakeholder engagements.

Table 5-8 Evaluation of the potential solutions in addressing key climate hazards in Uganda for maize value chain

Solutions	Climate hazards			Average rate
	Average temperatures/ Hot days over 35°C/ extreme heat and heatwaves	Days with rainfall > 20mm, and large 1-day rains	River and/or urban floods	
Harvesting machinery	4	2	1	2.33
Mechanical multi-crop threshers and shellers	4	4	4	4.00
Tarpaulins and plastic sheets	5	2	2	3.00
Wooden and metal cribs	4	2	2	2.67
Metal and plastic silos	4	5	4	4.33
Hermetic bags	4	4	4	4.00
Moisture meters	4	4	2	3.33
Storage structures	4	4	4	4.00
Storage protectants and control agents	4	2	2	2.67
Transport packaging	4	1	1	2.00

Table 5-9- Evaluation of the potential solutions in addressing key climate hazards in Uganda for beans value chain

Solutions	Climate hazards			Average rate
	Average temperatures/ Hot days over 35°C/ extreme heat and heatwaves	Days with rainfall > 20mm, and large 1-day rains	River and/or urban floods	
Harvesting machinery	4	2	1	2.33
Mechanical multi-crop threshers and shellers	4	4	4	4.00
Tarpaulins and plastic sheets	5	2	2	3.00
Wooden and metal cribs	2	2	2	2.00
Metal and plastic silos	4	5	4	4.33
Hermetic bags	4	4	4	4.00
Moisture meters	3	3	2	2.67
Storage structures	4	4	4	4.00
Storage protectants and control agents	4	2	2	2.67
Transport packaging	3	1	1	1.67

Based on the Table 5-8 and Table 5-9 the FL-RS with the highest average scoring is the following, presented in the order of importance:

- Metal and plastic silos (4.33 points for both maize and beans)
- Hermetic bags (4.00 points for both maize and beans)
- Mechanical multi-crop threshers and shellers (4.00 points for both maize and beans)
- Storage structures (4.00 points for both maize and beans)
- Tarpaulins and plastic sheets (3.00 points for both maize and beans)
- Moisture meters (3.33 points for maize and 2.67 points for beans)

- Storage protectants and control agents (2.67 points for both maize and beans)

Baseline research findings for Uganda (subchapter 5.1) confirmed by stakeholder engagements have identified harvesting and subsequent threshing, shelling and storage of beans and maize as critical loss factors, mainly due to manual labour, and lack of knowledge on the best postharvest management techniques. There is a growing need to mechanize harvesting, threshing and shelling processes for both maize and beans value chains within rural communities and among individual smallholder farmers. Such equipment can ensure proper threshing and shelling, reduce labour costs, and diminish both quantitative and qualitative physical crop losses.

Besides that, pest and rodent infestations represent another significant factor contributing to postharvest food losses in the maize and beans value chains in Uganda. They are most commonly caused by heat and inadequate storage facilities and techniques. Ensuring the storage of crops in durable, well-ventilated, and dry storage facilities (including both on-farm storage and wholesale or communal storage options) allows to significantly reduce those postharvest losses.

5.3.2 Solutions that can help with food loss reductions and have the potential to be scalable with smallholder farmers

In terms of solutions that would be accessible and scalable for smallholder farmers, factors such as affordability, durability and availability of those FL-RS were considered. Average estimations of prices for all 10 types of FL-RS in Uganda are presented in Table 5-10 below. For the evaluation, the scoring approach was employed, using the following grade: very high price (1 point), high price (2 points), moderate price (3 points), low price (4 points) and very low price (5 points).

Table 5-10 – Estimation of the costs of top 10 FL-RS in Uganda

Solutions	Estimated cost of the solution in Ugandan shillings	Estimated cost of the solution in US dollars	Scoring
Harvesting machinery	3 500 000 – 3 800 000	Est. 2 000 – 7 000	1
Mechanical multi-crop threshers and shellers	2 000 000 – 9 500 000	540 – 3 200	2
Moisture meters	950 000 – 1 800 000	250 - 490	3
Metal and plastic silos	150 000 – 710 000	Est. 25 - 200	3
Wooden and metal cribs	Not available	Not available	3
Storage structures	Not available	Not available	3
Tarpaulins and plastic sheets	85 000 – 550 000	23 - 150	4
Storage protectants and control agents	Not available	Not available	4
Transport packaging	25 000 – 50 000	7 - 14	4
Hermetic bags	7 500 – 15 000	2 - 4	5

Source: (JiJi Uganda, 2024)

Smallholder farmers in Uganda typically benefit most from solutions that are low-tech and familiar, as these are more accessible and easier for them to maintain. It's essential to provide technologies that they can readily obtain and integrate into their existing farming practices. To ensure the successful adoption and utilization of these technologies, it is equally important that farmers receive the necessary education and training. This involves building their capacity to use these tools effectively and sustainably. The RE-GAIN Programme addresses this need through Component 1, which focuses on capacity-building and awareness-raising activities. By enhancing their understanding and capabilities, farmers can better manage their resources, improve productivity, and reduce postharvest losses.

5.3.3 Solutions that are appropriate to the local context

In selecting solutions appropriate to the local context, it is critical to balance the climate challenges in the target regions with the awareness and utilization of these tools by smallholder farmers. The primary challenges for reducing postharvest losses in Uganda include the limited financial capacity of smallholder farmers to invest in mechanized high-tech solutions, coupled with restricted access to credit and bank loans. Additionally, quality low-technology solutions are scarce for harvesting, drying, and storing maize and beans coupled with insufficient knowledge regarding the optimal use of most food loss reduction solutions (FL-RS) available on the market.

In terms of key stages of postharvest losses identified for Uganda during the baseline assessments (Chapters 3 and 4), and the first round of stakeholder engagement on national and local levels, major losses in both maize and beans value chains are observed on the harvesting, threshing and shelling, and post-harvest handling and storage stages.

During the first round of stakeholder consultations in Uganda, participants of local and national workshops shortlisted the most important solutions, that would be relevant for both maize and bean production, as well as for building resilience against climate risks, and impact potential for smallholder farmers. The results of the shortlisting are provided in Table 5-11.

Table 5-11 Top solutions for maize and beans production, resilience against climate risks, and impact potential for smallholder farmers in Uganda

Relevance for maize production	Relevance for bean production	Relevance to build resilience against climate risks	Impact potential for smallholder farmers
Tarpaulins and plastic sheets	Tarpaulins and plastic sheets	Harvesting machinery	Tarpaulins and plastic sheets
Mechanical multi-crop threshers and shellers	Mechanical multi-crop threshers and shellers	Wooden and metal cribs	Hermetic bags
Hermetic bags	Hermetic bags	Mechanical multi-crop threshers and shellers	Mechanical multi-crop threshers and shellers
Metal and plastic silos	Metal and plastic silos	Storage structures	Storage protectants and control agents
Storage structures	Moisture meters	Transport packaging	Wooden and metal cribs

As we can see from Table 5-11, mechanical multi-crop threshers and shellers were included in all four categories, emphasizing the role of mechanization in the harvesting and post-harvest handling of maize and beans in Uganda. Tarpaulins and plastic sheets, as well as hermetic bags, were also among the priority FL-RS identified by stakeholders, as key solutions for drying and on-farm storage of maize and beans.

For the final evaluation provided in the Table 5-12 1 point was given for a single mention of the solution. Solutions that were not included, scored 0 points.

Among the other possible solutions, stakeholders identified their interest in using pallets for storage and transportation of big volumes of crops; and **community drying yards** - shared spaces used by agricultural communities for drying crops. These yards are essential for smallholder farmers who may not have enough land or resources to dry their produce individually. It might include features such as raised platforms made from cement or other similar durable construction materials; covers, or solar dryers to enhance the drying process and protect crops from pests and weather. Besides providing the required environment for drying, communal drying yards foster collaboration and knowledge exchange among farmers. Experienced farmers can share best practices and techniques for effective drying, benefiting the entire community. Capacity building and awareness raising on setting up and maintaining such drying yards will be considered in the Component 1 of RE-GAIN Programme.

5.3.4 Final evaluation

Taking into consideration all the above-mentioned factors, and considering the major climate risks for Uganda specified in the previous chapters, the physical FL-RS for Uganda with the highest potential to reduce postharvest food losses are highlighted in the Table 5-12 below:

Table 5-12 Final evaluation of the shortlisted physical FL-RS in Uganda

Solutions	Climate risks		Costs of the solutions	Best solutions in the local context	Final score
	Maize	Beans			
Harvesting machinery	2.33	2.33	1	1	6.66
Mechanical multi-crop threshers and shellers	4.00	4.00	2	4	14.00
Tarpaulins and plastic sheets	3.00	3.00	4	2	12.00
Wooden and metal cribs	2.67	2.00	3	2	9.67
Metal and plastic silos	4.33	4.33	3	2	13.67
Hermetic bags	4.00	4.00	5	3	16.00
Moisture meters	3.33	2.67	3	1	10.00
Storage structures	4.00	4.00	3	2	13.00
Storage protectants and control agents	2.67	2.67	4	1	10.33
Transport packaging	2.00	1.67	4	1	8.67

Detailed evaluation of their advantages, disadvantages, and existing barriers to the implementation of those shortlisted FL-RS within the Re-GAIN Programme is provided in the next subchapter.

5.4 IN-DEPTH EVALUATION AND PRIORITISATION OF SHORT-LISTED FL-RS

Based on the results of stakeholder engagements in Uganda, each out of shortlisted physical solutions were evaluated, including key strategic points such as the advantages and disadvantages of each solution, and key barriers to their use particularly in the context of smallholder farmers. The results of the evaluation are provided in Table 5-13 .

Table 5-13 Results of the shortlisted FL-RS evaluation in Uganda

Solution	Strategic advantages of the solution	Key disadvantages of the solution	Key barriers to solution implementation	Additional points based on the baseline research results and discussions with stakeholders
Mechanical multi-crop threshers and shellers	Simplify the post-harvest process, enhancing efficiency and producing high-quality grain. These machines are affordable, add value to the harvest, and are portable and locally manufactured.	Maintenance challenges, require skilled labour, and are difficult to transport, especially in hilly areas. They are not ideal for large-scale production and cannot consistently ensure high-quality seeds	High purchase and maintenance costs, a need for mindset change among farmers, inadequate training systems, limited financial resources, and accessibility issues	They expedite harvesting activities and are appropriate for various scales of farming, but require skilled manpower and appropriate training on use and maintenance
Tarpaulins and plastic sheets	Advantageous due to their affordability, ease of use, and moisture control capabilities. They are readily accessible, appropriate for smallholder farmers, and multipurpose for cereal storage	Prone to counterfeits, susceptible to damage by birds, animals, pets, and termites, and inefficient for handling large volumes	Cost for rural farmers, the need for a mindset change, limited accessibility, and concerns about long-term sustainability	Might be easily damaged if not managed appropriately, which also creates increased plastic use. Training would be beneficial to ensure their multi-time use and quality maintenance
Hermetic bags	Effective for pest control and are suitable for	Can be destroyed by rodents and termites,	Need for a mindset change,	Farmers need training and improved knowledge on the proper use and

Solution	Strategic advantages of the solution	Key disadvantages of the solution	Key barriers to solution implementation	Additional points based on the baseline research results and discussions with stakeholders
	smallholder farmers. They are affordable, multipurpose, and help minimize the use of chemicals. These bags are widely available and provide excellent long-term storage	are not cost-effective for bulk handling, and can be expensive over time	limited accessibility, high costs for poor farmers, and vulnerability to rain	maintenance of those bags, as well as opportunities for the bags' disposal for recycling
Moisture meters	Provides accurate measurements, ensuring that grains are properly dried, and aiding in the detection of moisture levels. Helps to maintain the quality of the grains, reducing post-harvest losses, and improving overall efficiency in processing	Requires skilled manpower to operate them accurately which can be a significant hurdle. Cost of these devices makes them unaffordable for many smallholder farmers, limiting their accessibility and widespread adoption	The primary challenge is the lack of funds. Furthermore, even if the equipment is available, proper training is required for farmers to use it effectively	Suitable and effective solution for the community level. Farmers usually need to check the level of moisture before storage, and during storage
Metal and plastic silos	Provide long-term grain preservation, maintaining quality and protecting against pests and rodents. They are portable, durable, and flexible storage options	Smallholder farmers require capacity building to use them effectively	High cost, limited affordability, and availability, especially for smallholder farmers	Allow grain preservation for a longer period of time, particularly in extreme weather conditions. Frequently referred to as prone to theft
Storage structures	Preserve grain quality for extended periods. They offer good pest control and aeration and are beneficial for farmer groups and cooperative societies	Vulnerable to theft, rodents, and high maintenance costs. They may also be susceptible to insect and pathogen infestations and require significant space	High cost of construction, lack of funds, and the need for training and skills for storage structure maintenance	There is a need for storage structures on community levels. Numerous stakeholders identified the need for community-managed or government managed storage facilities, that would be accessible to farmers
Storage protectants and control agents	Easy to use, accessible, and effective in pest protection	Not durable, poses health risks, and may be destroyed by rodents. The improper use of chemicals can result in residual health effects for consumers and presents environmental hazards	Affordability, availability, and the need for appropriate training and knowledge on usage	Framers often lack technical skills on the dosage of those control agents, and access to more natural/organic insecticides and fungicides, which also can be more expensive than the ordinary chemical ones

These assessments facilitated the development of a shortlist of seven relevant physical FL-RS solutions that could be tailored to meet specific country needs. This shortlist aims to guide the final selection of solutions to be supported and disseminated by the RE-GAIN programme.

In addition to the above-mentioned prioritizations following the climate rationale, the final selection of solutions considered additional prioritization factors to ensure the success of the RE-GAIN Programme and achieve lasting systemic changes in all target countries. These include:

- Impact of the solution on the environment (environmental pollution/ GHG emissions during the use of the solutions),
- current level of awareness of the farmers about the solution's proper use and maintenance,
- frequency of the solutions' uses during the year,
- solution's estimated potential in reducing food losses,
- availability of selected FL-RS in the country, and
- potential for the supply scalability and job creation through locally produced or assembled solutions and improving market linkages.

Given these factors, affordable solutions such as solar-powered small-scale mechanized solutions with the highest potential to protect harvests from high moisture and pests are prioritized.

Additionally, considering the critical loss points for the target crops, particularly during post-harvest handling and storage, proper access to appropriate storage technologies for farmers is essential. Combining hermetic storage solutions (hermetic bags, silos, storage structures) with moisture meters is crucial for preventing spoilage and aflatoxin development, particularly in crops like maize and groundnut. This combination offers an enhanced opportunity to reduce food losses effectively.

To further prioritize the list of solutions for each country, a high, medium, and low scoring approach was applied, considering synergies and increased potential impact of the solutions on food loss reduction. The final shortlist of prioritized solutions for each country is presented in Table 5-14:

Table 5-14 Prioritized physical FL-RS for Uganda

Solutions	Level of priority
Harvesting machinery	low
Mechanical multi-crop threshers and shellers	high
Tarpaulins and plastic sheets	high
Wooden and metal cribs	low
Metal and plastic silos	high
Hermetic bags	high
Moisture meters	medium
Communal storage structures	high
Storage protectants and control agents	medium
Transport packaging	low

Based on the above, we propose delivery of shortlisted solutions using the following approach:

- Communal use by the target communities/farmer groups: harvesting machinery, mechanical multi-crop threshers and shellers (preferably solar-powered), moisture meters and communal storage structures
- Individual use by the target farmers: tarpaulins and plastic sheets, metal and plastic silos, hermetic bags, and storage protectants and control agents.

Considering the above mentioned points, we recommend the FL-RS adaptation strategy for Uganda to be deployed as a basket of options, bespoke combinations such as mechanical multi-crop threshers and shellers (preferably solar-powered) combined with moisture meters for monitoring the level of moisture in the target crops, and communal storage structures, with the FL-RS uses on the individual farm level, such as tarpaulins and plastic sheets for drying crops, and hermetic storage technologies (hermetic bags, silos) used for storage of the crops.

Taking into consideration the shortlisted solutions for Uganda, as well as their potential to reduce postharvest losses and existing barriers, Table 5-15 provides a brief overview of the proposed solutions' delivery mechanism for Uganda.

Table 5-15 – Proposed delivery mechanism for shortlisted physical FL-RS in Uganda

Solution	Estimated reduction in PHL, % (Table 5-1)	Barriers to solution implementation	Proposed delivery mechanisms
Mechanical multi-crop threshers and shellers	10-30%	• High purchase and maintenance costs • Inadequate training systems • Accessibility issues	• Improved access to solutions through a subsidy scheme

Solution	Estimated reduction in PHL, % (Table 5-1)	Barriers to solution implementation	Proposed delivery mechanisms
			• Capacity building (training of trainers) on managing and maintaining the machinery
Tarpaulins and plastic sheets	10-20%	• High cost for rural farmers • Limited accessibility • Concerns about long-term sustainability	• Improved access to solutions through a subsidy scheme • Training and capacity building on the appropriate use of tarpaulins and plastic sheets
Hermetic bags	20-30%	• Limited accessibility • High costs for average farmers • Need for appropriate training and knowledge on usage	• Improved access to solutions through a subsidy scheme • Training and capacity building on the appropriate use of hermetic bags
Moisture meters	Up to 25%	• Limited accessibility due to cost • Lack of knowledge of proper use and maintenance	• Improved access to solutions through a subsidy scheme • Training and capacity building on the appropriate use and maintenance
Metal and plastic silos	10- 50%	• High cost/ limited affordability • Limited availability	• Improved access to solutions through a subsidy scheme • Training and capacity building on the appropriate use of silos, and their maintenance
Storage structures	Up to 15%	• High cost of construction/ lack of funds • Need for training and skills for storage structure maintenance	• Improved access to solutions through a subsidy scheme • Capacity building (training of trainers) on the best practices in using and maintaining storage structures
Storage protectants and control agents	30-40%	• Affordability • Availability • Need for appropriate training and knowledge on usage	• Improved access to solutions through a subsidy scheme • Training and capacity building on the appropriate use of storage protectants and control agents

For the successful implementation of RE-GAIN programme in Uganda it is also critical to consider additional aspects and factors, such as improved access to finance for women and youth groups, traditional roles of both genders in the agricultural sector, land tenure/ ownership rights, and the ways communities operate in the Programme's target regions.

5.5 RECOMMENDATIONS AND PROGRAMMATIC CONSIDERATIONS FOR INTRODUCTION OF FOOD LOSS REDUCTION SOLUTIONS (FL-RS)

To ensure the success of the RE-GAIN Programme and achieve lasting systemic changes across the target countries beyond the programme's duration, several key factors must be in place:

- Strong alignment of the proposed physical solutions with the capacity-building and awareness-raising activities
- Availability of selected FL-RS in the country, and potential for the supply scalability

- Focus on strengthening market-driven approach, and developing strong market linkages
- Efficient communication and information dissemination about the programme
- Proactive inclusion of women in the training and capacity-building activities
- Effective financing mechanisms
- Enabling environment for the uptake of FL-RS

Strong alignment of the proposed solutions with the capacity-building and awareness-raising activities

Raising awareness is a fundamental for reaching a large number of smallholder farmers and MSMEs, motivating them to adopt and increase the use of FL-RS. Training and capacity-building efforts focused on the technical and managerial aspects of FL-RS are vital for the program's success. These efforts will enhance farmers' understanding of climate information, the effects of climate change on harvest and post-harvest activities, and the practical application of FL-RS to significantly reduce food losses. This, in turn, will support farmers in boosting food security, increasing income, and ensuring a return on investment, all contributing to the overall success of the program. The requirements for awareness-raising and capacity-building, which are key to achieving these outcomes, have been detailed earlier in this chapter. These activities will not only empower farmers but also strengthen their ability to adopt sustainable practices that are essential for long-term resilience and program sustainability.

Availability of selected FL-RS in the country, and potential for the supply scalability

The success of the RE-GAIN Programme relies heavily on the availability, affordability, quality, and scalability of the selected FL-RS technologies. These include harvesting machinery, mechanical multi-crop threshers and shellers, tarpaulins, plastic sheets, metal and plastic silos, hermetic bags, moisture meters, and storage structures. It is crucial that these technologies not only exist in sufficient quantities within the market but also remain continuously accessible to target farmers in remote and rural areas, both during and after the programme.

This will be accomplished through market mapping and the development of a robust network of local manufacturers and importers/agro-dealers to assess the current supply of FL-RS and their potential for scalable production, as part of creating sustainable market linkages. To ensure FL-RS reach remote regions, stronger collaboration between solution manufacturers and local agro-dealers will be essential. This partnership will help guarantee both the availability and accessibility of these solutions for farmers, fostering long-term adoption and sustainability.

Focus on strengthening market-driven approach, and developing strong market linkages

For RE-GAIN Programme to create sustainable change, it will focus on fostering market linkages between smallholders, MSMEs, and potential buyers such as retailers, processors, and exporters using AGRA's proven consortia model. This will build on the market mapping, which will identify key agricultural value chain actors, including potential institutional markets not yet fully accessible to smallholders. Utilising this information, the RE-GAIN Programme will support farmers in connecting with other actors in the value chain, including providing technical assistance to secure formal off-take agreements for produce that meets quality standards of institutional markets.

Efficient communication and information dissemination about climate risk and the programme

Effective communication about the programme, its goals, and its benefits—notably reducing post-harvest food losses amid changing climate conditions—is vital for achieving successful outcomes across all seven countries. Communication efforts will focus on ensuring that available weather information is widely shared, complemented by the development of informational materials. A dedicated communication platform will be established, enabling FL-RS suppliers, manufacturers,

and other key stakeholders to communicate with one another and provide information on their available solutions. Additionally, outreach to farmers, including details on available financial resources like bank loans and FL-RS distribution opportunities, will be facilitated through village-based advisors, ensuring that essential information reaches even the most remote communities.

Proactive inclusion of women, youth, and Indigenous people (where present) in the training and capacity-building activities

As identified during the stakeholder engagements and confirmed by the official data, women, youth and indigenous people (where present) play crucial roles in the agricultural sector in Sub-Saharan Africa, especially in the stages of harvesting and post-harvest handling. Therefore, it is critical to ensure their efficient representation and active participation in the capacity building and awareness raising activities of RE-GAIN programme. This will be achieved by targeted selection of participants/ audience for the capacity-building activities. Beyond this, RE-GAIN will also encourage MSMEs to engage with informal youth groups to engage in the services provision of FL-RS services, in which the youth groups will operate under the supervision and contractual responsibility of the MSMEs, ensuring accountability and providing the youth group with an opportunity to build a track record of successful operations and governance.

Effective financing mechanisms

Effective financing mechanisms are crucial for expanding access to food loss reduction solutions across all seven countries. These mechanisms are particularly important when the benefits and return on investment for harvest and post-harvest technologies are not yet well-established among smallholder farmers and agribusinesses, and when the private sector needs to develop new product-market combinations. The delivery of physical FL-RS to farmers and other target stakeholders, facilitated by these financial mechanisms, will begin in the second year of the programme, ensuring that access to these solutions is supported by sustainable financial models that foster long-term adoption and growth.

Enabling environment for the uptake of FL-RS

For the successful implementation of the RE-GAIN programme, it is essential to prioritize activities that ensure its long-term sustainability. As the programme builds knowledge about climate risks and their impact on agriculture, enhances both the demand for and supply of FL-RS, improves access to financing, and strengthens market linkages, it will also focus on supporting policy development and reform. Key policy initiatives will include advocating for tax exemptions, establishing certification and quality standards for FL-RS, promoting scalable and replicable FL-RS business models, and improving the accessibility of weather information for smallholder farmers.

Active involvement and support from both central and local government organizations will be critical to the programme's success. The RE-GAIN programme will align with other relevant projects and initiatives to create synergies, leverage existing laws and policies related to food loss reduction, MSME development, and smallholder support, and ensure effective programme management. This will involve rigorous monitoring, continuous improvement, and the integration of lessons learned to enhance outcomes and ensure long-term impact.

5.6 PROPOSED DESIGN OF THE RE-GAIN PROGRAMME

The RE-GAIN programme tackles climate change and food losses by addressing both physical and non-physical solutions within the selected value chains. It is organized into three key components and five targeted outputs; each designed to maximize impact and ensure a comprehensive approach to reducing post-harvest losses. Each component is designed with

targeted activities to improve awareness, access, and the enabling environment, all aimed at increasing the adoption of FL-RS and driving significant reductions in post-harvest food loss. The expected outputs and respective activities, together with the identified barriers they aim to address, are presented in Table 5-16:

Table 5-16 Proposed Activities Set and Outputs of the RE-GAIN Programme, aligned with the identified risks, needs and barriers in access to FL-RS

Identified risks, needs and barriers	Activity sets	Outputs
Technical and Operational Challenges • Technical challenges in use of technologies and equipment • Susceptibility of crops to weather conditions, pests, and contamination • Limited access to markets for smallholder products • Limited awareness of impact of climate change on harvest and post-harvest crop management • Limited awareness of the use of climate information for decision making Skills and Knowledge Requirements • Limited awareness of impact of climate change on harvest and post-harvest crop management • Limited awareness of the use of climate information for decision making • Need for proper training, knowledge, and technical skills for effective use and maintenance of equipment and post-harvest technologies • Limited awareness and knowledge about proper usage and management of FL-RS Health, Safety, and Environmental Risks • High pollution risks and environmental impacts of certain harvesting technologies • Health and safety concerns associated with the use of chemical products as storage protectants	Activity Set 1 • Gender-responsive awareness campaign on the impacts of CC on post-harvest food losses and the availability of FL-RS. • Demonstration, training and tech. transfer for the use of weather/ climate information, FL-RS and related practices • Capacity development of extension services and agro-dealers	Output 1.1. Smallholder farmers supported to adopt FL-RS
	Activity Set 2 • Facilitate market linkages between institutional markets & other buyers & smallholders, Support to structuring of value chains & coordination between market actors	Output 1.2. Improved market linkages between agri-value chain actors
Cost and Economic Constraints • High initial costs and ongoing maintenance expenses of machinery and technologies • Affordability challenges, especially for vulnerable communities • Lack of capital and limited access to finance • Inaccessibility of fuel and high fuel costs in some areas, high energy consumption and maintenance requirements of harvesting machinery Market constraints • Lack of available FL-RS, especially in remote and rural areas • Limited accessibility and (perceived) high cost of FL-RS, especially in rural areas • Limited availability of quality materials and resources for production of FL-RS	Activity Set 3 • Provide business development support & market intelligence for FL-RS manufacturers • Capacity and market development for all market actors • Training of new FL-RS providers (MSMEs, cooperatives, incl. women- and youth - led initiatives) • Facilitate access to finance for FL-RS providers through innovative de-risking schemes	Output 2.1. Business development support for the improved provision of FL-RS on local markets
	Activity Set 4 • Support inclusion of FL-RS in climate-resilient input packages • Structure prefinancing partnership arrangements that include FL-RS • Facilitate the development and deployment of smart subsidy and catalytic grant models, as well as 'lease-to-own models for FL-RS focussing on women and youth as key beneficiaries.	Output 2.2. Financial mechanisms for smallholders and MSMEs to support the adoption of FL-RS

Identified risks, needs and barriers	Activity sets	Outputs
Quality and Reliability Concerns • Variable quality and limited durability of FL-RS present in the market, affecting their reliability Other concerns • Lack of access to solutions and agricultural finance for women • Limited awareness among farmers about the effectiveness and economic benefits of FL-RS	Activity Set 5 • Support the revision of policies that enable FL-RS investments, including tax exemptions, certification and standards for FL-RS quality • Promote successful FL-RS business models for scaling-up & replication	Output 3.1. Enhanced capacity of national institutions to enable investments in FL-RS

5.7 OVERVIEW OF IMPLEMENTATION ARRANGEMENTS

For the RE-GAIN to be a successful programme, it will leverage AGRA's expertise both from its headquarters as well as its country offices.

AGRA HQ senior leadership and technical leads will be responsible for the overall supervision and coordination of the project including ensuring: i) funds are effectively managed to deliver results and achieve objectives; ii) the quality of project monitoring; and iii) liaison with the GCF. AGRA will also leverage expertise from its wider technical leadership and support by AGRA's Heads of Markets and Trade, Inclusive Finance, Sustainable Farming, Private-sector Partnerships, Strategy, Policy and State Capability, Monitoring and Evaluation and Knowledge Management. The AGRA HQ team will be the primarily liaison with the GCF.

5.7.1. Executing Entity (EE)

The project will be executed directly by AGRA through its) Programme Implementation Unit (PIU). Through this unit, AGRA will provide key resources, including Finance, Grant Management and Procurement Officers who will provide financial and administrative management, overseeing financial, contractual, procurement and logistics aspects for the project from the Nairobi Headquarters. The unit will oversee planning and quality assurance; supervise programme monitoring, evaluation and reporting; ensure timely realization of all programme deliverables; provide leadership and technical support to implementing partners; and ensure smooth communication flow across all programme partners. This executing role will be fulfilled both through the Nairobi-based headquarters, and AGRA's country offices, and will report to the AGRA senior leadership.

The EE is responsible for:

- Execution of the project,
- Procurement of services specifically (major procurement and Subgrant contracting),
- Facilitating partnerships,
- Managing contracts, monitoring results,
- Annual reporting by county offices to the PIU

AGRA deploys a diverse set of delivery models to deliver its country and institutional strategy. It offers services through its **expert staff**, placed at headquarters in Nairobi; at the East, Southern and West Africa regional offices; as well as at country offices. AGRA staff work with downstream partners and local organizations to implement **specific components** of a contracted programme area with the aim to improve local organizations' capacity, build institutional capacity and ensure long term ownership and sustainability of its interventions. AGRA provides **Technical Assistance (TA) in the form of short- to medium-term expertise support** (through consultants where needed) embedded within or seconded to mandated national, regional and continental institutions (e.g., government ministries, regional economic communities) to drive desired change, and in

some instances consultants are hired to support specific assignments that require skilled expertise. AGRA is a **convener (brings stakeholders together around a change agenda, e.g., the Africa Food Systems Summit)** facilitating connections and interactions between different actors and stakeholders within the agriculture and food systems sector. AGRA utilizes advocacy and communication as key tools for change. The specific delivery models will be determined at the implementation stage and will depend on each country context.

5.7.2. Responsible Units

The EE team at the Nairobi HQ will be supported by AGRA country offices in each of the seven target countries who will serve as responsible units. These units will support on-the-ground coordination and implementation, as well as being mandated for specific outputs/activities.

5.7.3. Programme Governance

Programme Advisory Group:

AGRA will establish a Programme Advisory Group (PAG) made up of senior representatives from AGRA's Integrated Programme Management (IPM) unit[3] that will serve as the starting point to guide innovation, impact scale and adaptive thought leadership to shape the partnership at continental level. AGRA envisions this Advisory Group will meet quarterly as part of IPM meetings

Programme Implementation Unit

A central Programme Implementation Unit (PIU) will be established at AGRA's Nairobi headquarters to oversee implementation of the entire programme across all seven countries. This unit will report to the PAG and be comprised of two sub-groups; a Programme Management Unit (PMU) and a Technical Expert Group (TEG), as described below.

- *Programme Management Unit*

  The Programme will establish a management unit that will be functional for the entire duration and be responsible for day-to-day implementation of the project. The PMU will offer overall management, implementation and general technical direction of the entire programme, ensuring an integrated vision among different components. The PMU will consist of five full time positions: i) PMU Lead; ii) Senior Finance Officer; iii) Procurement Officer; iv) Project Analyst; and v) M&E Officer. The PMU will be based in AGRA Nairobi Headquarters, with in-country support from responsible units in the country offices.

- *Technical Expert Group*

  The TEG, also situated within the Nairobi Headquarters, will provide expertise to assist the PMU in the technical implementation of the RE-GAIN programme. The TEG will include several full-time positions, including: i) Program Officer — Gender, Youth and Inclusion; ii) Technical Advisor — Inclusive Finance and BDS; iii) Technical Advisor — Extension and Value Chain Development. These full-time roles will be supported by several part-time technical team members, including: i) Technical Advisor — Inclusive Markets and Finance; ii) Lead — Sustainable Farming, Distribution and Youth in Extension; iii) Technical Advisor — Livelihood Resilience and Climate Adaption; iv) Head: M&E; and v) Technical Advisor — Food Loss Reduction Analytics.

[3] Vice presidents, relevant business line or programme directors/heads, Lead of PMU , Head of MEL

Country-level Implementation Units

The PIU will be assisted in project implementation within each target country by a country-level implementation unit (CIU) which will be established in each of the AGRA country offices[4] and will be comprised of country-office staff. The CIUs will be responsible for managing day-to-day operations in each country, reporting directly to the PIU, as well as providing regular reports to the relevant Project Steering Committee (see below).

Programme Steering Committee

At the country level, the programme will be implemented under the overall guidance of a Programme Steering Committee (PSC) co-chaired by a representative of the NDA, and AGRA country managers. The PSC will include representatives of other key government departments and agencies, the private sector and civil society organizations. These partners will likely include Ministries of Agriculture and their Departments for Land Resources Conservation, Crop Development, Agriculture Extension Services and Agriculture Planning Services. The role of the PSC will be to: i) provide overall guidance and direction to the project in country; ii) address project issues as raised by the advisory group; iii) review the project progress and provide direction and recommendations to ensure that the agreed deliverables are produced satisfactorily and within the approved project framework; iv) review and approve annual work plan and budget (AWPB) and provide necessary strategic guidance for its implementation; v) appraise the annual project implementation report, including the quality assessment rating report; vi) make recommendations for subsequent work plans to build on achievements and address any shortcomings; and vi) provide ad hoc direction and advice for exceptional situations or when requested by the GCF, strategic advisory group or PSC members.

Each national PSC will include representatives of private sector actors in addition to key government institutions. A list of potential private partners is presented in Appendix 9 of Annex 2. The selection of specific partners for each country will be led by AGRA and will be dependent on specific criteria as outlined in Annex 2. At country level there will annual forums for feedback and policy dialogues that will be organized by each county office. The lessons learned through the project monitoring, evaluation and learning systems in each participating country will be shared to all other participating countries through two approaches: i) Cross-country presentations at AGRA's internal Quarterly Performance Review Meeting, where all country directors and program officers participate; and ii) an annual planning and review session organized by the PMU in which all countries and partners participate to promote cross country learnings, exposure and innovation. In addition, at continental level, the AFSF will organization special sessions for cross country learning and feedback.

Each National PSC will convene in an interval of 3 months (quarterly) with a provision for additional extraordinary meetings when required and to be called by the chair and co-chair or if requested by members. The PSC will report to the NDA who oversees all GCF project in the individual countries.

Table 5-17: Country PSC Representatives

Country	PSC Representatives
Uganda	• Ministry of Agriculture Animal Industry and Fisheries (MAAIF) • Ministry of Trade, Industry and Cooperatives (MATIC)

[4] Which fall under the same legal entity as the PSAA Applicant

Stakeholder Engagement

Across the different countries, AGRA will liaise with different governmental agencies during the implementation of the different outputs to ensure that the RE-GAIN programme is aligned with country-specific policies. A non-exhaustive list of these stakeholders is provided is section B.4 of the funding proposal band will be further updated through engagement with the NDA's selected representative in each country.

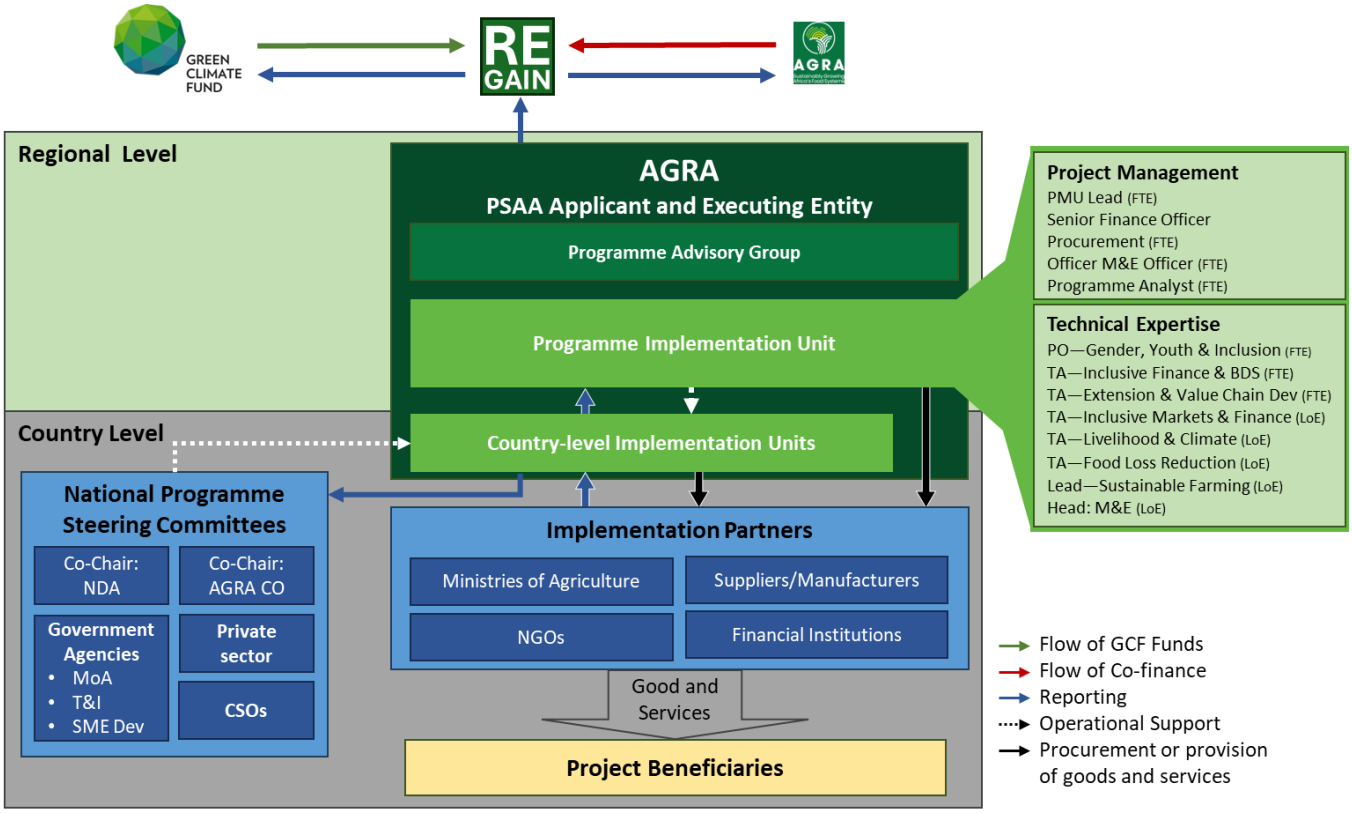

Figure 5-17 Implementation Arrangements for the RE-GAIN Programme

5.8 PROGRAMME AREA

Climate risks were carefully considered for the countries under consideration (as detailed in Chapter 3), evaluating factors to identify locations that align with the programmes goals. This analysis helps us make informed decisions, ensuring the selected location is well-suited for long-term success without causing any adverse impacts. Alongside this assessment, we have carefully considered the additional criteria listed below to further refine our choice, ensuring a holistic approach to decision-making.

5.8.1 Eligibility criteria for programme area

- Selection of geographical location in the target countries for the RE-GAIN project. Below is the selection criteria that will be considered:
- Areas that have significant smallholder agriculture production.
- Production areas that are recognized by local government as high productivity areas. Consultation will be key in the selection process

- Proximity to or existing agro-dealer network and or agriculture input and output businesses,
- Where selected value chains are being produced and or traded
- Where there is existing AGRA investments in extension systems, enhanced productivity and support to market systems
- Areas that have previously and are currently being serviced by financial products by financial institutions
- Existing infrastructure communications infrastructure to allow accessibility to the area
- Demographics: Areas that have a potential for spillover or scaling effect due to the existence of a significant number of value chain actors (farm to market).
- Synergies with other existing projects and initiative

6 Market Dynamics Study

RE-GAIN Programme is designed to promote market-led adoption and implementation of FL-RS, to reduce food losses, increase incomes and contribute to climate change adaptation and mitigation. Under Component 1 the market demand for FL-RS will be stimulated through awareness raising, capacity building, demonstrations and other activities (Chapter 5.2.1). Under Component 2 the supply of FL-RS will be stimulated through support for FL-RS manufacturers and traders and providing access to finance for smallholders so that they can invest in the FL-RS, while under Component 3 the market linkages (for FL-RS) between agro-value chain actors will be improved. This chapter describes the supply and demand for prioritized FL-RS, the supply of FL-RS and Financial Services.

6.1 CURRENT DEMAND AND SUPPLY OF THE PRIORITISED FL-RS

The demand and supply of agricultural machinery and other post-harvest food loss reduction technologies among smallholder farmers in Uganda reflects existing challenges and opportunities within the sector. Literature reviews and stakeholder consultations confirmed the presence of several barriers that impede the demand for improved FL-RS in Uganda, including:

a) Lack of information and awareness about the importance of food losses and available postharvest technologies.
b) Lack of appropriate knowledge and skills within the farming community that hinders the adoption of modern agricultural techniques and more efficient resources management.
c) Low literacy levels among women farmers which hinders their full participation in awareness and training activities, inhibiting their adopting improved agricultural activities, including FL-RS.
d) High cost of some of the FL-RS, such as threshes/shellers, silos, moisture meters and even hermitic bags making them unaffordable.
e) Poor market linkages and market and product information asymmetries which hamper farmers' ability to connect effectively with suppliers.
f) Limited supply of affordable finance due to high interest rates, short loan periods, or lack of access to collateral, limits farmer's access to loans for investing in FL-RS.
g) Unstable market prices add another layer of uncertainty, making it difficult for farmers to plan and invest in their operations confidently.

Below we explore specifics on the demand and supply of the specific prioritized physical solutions discussed in the previous chapter.

6.1.1 Demand for specific FL-RS

The demand for FL-RS in Uganda highlights the critical need for affordable and high-quality solutions to enhance agricultural productivity and reduce post-harvest losses.

Mechanical multi-crop threshers and shellers are highly sought after in Uganda. They are particularly beneficial for medium-sized farmers growing diverse crops, as they significantly boost productivity and lower labour expenses. However, several factors constrain their widespread adoption in Uganda, including but not limited to high cost of equipment and limited local manufacturing.

Tarpaulins and plastic sheets are widely used in Uganda for drying crops like maize and beans. The supply chain for these products is robust, with both imported and locally produced options available on the market. However, affordability remains a significant issue. High-quality tarpaulins are crucial for maintaining farmer interest, but such products are often in short supply and can be expensive. Ensuring the availability of affordable and durable tarpaulins is essential to support the drying process and prevent post-harvest losses.

Hermetic bags have seen a surge in demand in Uganda, as well as in other African countries, due to their effectiveness in protecting stored grains from pests and spoilage. Increased awareness and a growing network of suppliers have improved their availability. Nonetheless, these bags are still relatively expensive and sometimes not durable, primarily due to improper usage by some farmers. Knowledge and capacity gaps contribute to this issue. Additionally, the market is sometimes flooded with cheap imitations sold as high-quality hermetic bags, which fail to protect crops and risk future investments.

The demand for **metal and plastic silos** in Uganda is moderate. These silos, while effective for grain storage, come with high costs and require proper installation and maintenance. Farmers may hesitate to invest in them due to their immobility and susceptibility to theft.

Moisture meters are getting more popular as Ugandan farmers recognize their role in preventing spoilage. However, most moisture meters are imported, making them expensive and limiting their distribution. There is a significant need for training programs to educate farmers on the proper usage of moisture meters, which would help maximize their benefits and justify the investment.

There is a high demand for **improved storage structures** to reduce post-harvest losses and enable farmers to store crops longer to achieve better prices. However, the availability of modern communal storage solutions is low, primarily due to their high costs. Smallholder farmers often rely on traditional structures, which are less effective. Moreover, modern storage facilities require proper management and maintenance, adding to the complexity and cost of their development. Enhanced access to affordable storage solutions and management training would significantly benefit smallholder farmers.

Storage protectants and control agents in Uganda are facing stable demand. However, challenges such as the high cost of quality protectants, limited availability, and inadequate regulatory frameworks to prevent the sale of substandard products impede their widespread use. Additionally, many farmers lack the knowledge to use these protectants effectively and safely, highlighting the need for better extension services and training programs.

6.2 MARKET OF SUPPLIERS AND MANUFACTURERS OF FL-RS

The supply side of FL-RS in Uganda is characterized by several challenges and dynamics that impact the availability and affordability of essential agricultural equipment and materials.

Agricultural sector in Uganda often relies on expensive imports to meet the demand for FL-RS. This dependence on imports makes these resources costly for farmers, especially when factoring in shipping, tariffs, and other import-related expenses. Besides that. FL-RS market in Uganda is highly fragmented, consisting of companies and service providers operating at different scales. This fragmentation means there are many players, each with varying capacities and market reach. While this can foster competition and potentially lower prices, it also leads to inconsistencies in quality and availability.

On the positive side, numerous manufacturers and importers of priority FL-RS operate both regionally and locally within Uganda. These entities are primarily located in major cities, where they can leverage better infrastructure and connectivity. They collaborate closely with agricultural dealers and service providers to facilitate the distribution of FL-RS across the country. Those agricultural dealers and service providers play a crucial role in engaging directly with smallholder farmers, cooperatives, and associations. They sell the equipment and other solutions directly to these end-users or offer them on a rental basis for specific periods.

The largest agricultural machinery companies such as Machines Equipment, Industrial Machines Uganda, Tractors Uganda, and others provide agricultural machinery solutions such as **mechanical multi-crop threshers and shellers**, tractors and harvesting machinery. They mainly import the threshers, and then distribute their products across the country through a network of dealers and agricultural machinery suppliers. The estimated supply capacity varies depending on the company. Specific information about major Ugandan suppliers of FL-RS including their capacities, main solutions produced/supplied, and whether those solutions are locally produced or imported, together with the average costs of solutions, is provided in the Appendix 9.

Among the prioritised FL-RS for Uganda, **tarpaulins and plastic sheets** are commonly available and are predominantly produced locally. One of the key manufacturers is Naskan General Hardware Smc Limited, which plays a crucial role in supplying these essential agricultural materials. Local production helps in maintaining a steady supply and potentially reduces costs associated with importation. Agricultural dealers then distribute tarpaulins directly to farmers, ensuring that they are readily accessible where they are needed the most. This direct distribution network is vital for meeting the immediate demands of farmers, especially during peak harvesting seasons.

In addition to local agricultural dealers, tarpaulins and plastic sheets are also available through various online platforms, expanding the accessibility for farmers. Online shops such as Ubuy and UNISIGN offer a wide range of these products. These platforms provide farmers with the convenience of comparing prices and selecting from a variety of options without the need to travel.

Hermetic bags are among the most popular primary physical solutions in Uganda. There are both imported, and locally manufactured hermetic bags present in the Ugandan market. Leading suppliers/importers in this sector are Uganda Crop Care, Agroking Uganda Ltd, Luuka Plastics, Bukoola Chemicals, among others. The bags then being distributed and sold through local vendors.

Metal and plastic silos in Uganda are being both locally produced and imported, by the big companies such as Steel&Tube, Crestanks, Mudher Industrial Park and others. They come in a variety of capacities, starting from 100 litres and up to 7,000 liters/ 2 to 6 tonnes. Prices vary depending on the material (plastic or metal), and the overall capacity.

Moisture meters in Uganda are primarily imported by measuring equipment and agricultural equipment companies such as Eagle Weighting Systems, among others, which also provide distribution services throughout the country, often partnering with agrodealers and other third-party distributors to reach a wide range of customers in both urban and rural areas.

Improved communal **storage structures**, such as communal grain sheds, are being either produced in the country, or imported as prefabricated items (primarily from China) and assembled locally. Few private sector companies offer these kind of storage structures for sale. Those companies include Steel&Tube, and Crestanks. Those companies usually work with imported raw materials, but then assemble/produce the storage structures locally in Uganda.

As for the **storage protectants and control agents**, companies such as Uganda Crop Care and others import those from other countries. Majority of their products are of chemical origin, and therefore Ugandan market need to produce/import more organic/ natural storage protectants and control agents.

6.3 ACCESS TO FINANCE

Innovative financing models tailored to the needs of smallholder farmers can improve both access and affordability by relieving farmers of the need to securitize loans, mitigating the burden of high interest rates or compressed repayment periods, thus facilitating access to necessary capital. Among the crucial ways to resolve existing financial barriers, RE-GAIN Programme proposes to explore the following opportunities:

- Support and test/ pilot the development of financial products tailored for agriculture MSMEs.
- Leverage partnerships between financial institutions, NGOs and MSMEs, to redistribute the burden of risks and costs (such as interest rate costs) and enabling access to working capital for farmers to purchase FL-RS
- Link MSMEs to organizations that can provide basic business management and recordkeeping capabilities, bringing them into line with information thresholds for banks' creditworthiness checks.

6.3.1 Barriers to access

6.3.1.1 Smallholder farmers barriers to FL-RS adoption

The benefits and importance of using FL-RS are not known or not implementable by all smallholder farmers across the RE-GAIN programme's target countries. Adoption of new technology by farmers requires awareness creation and evidence that adoption of the FL-RS will give a return on investment to farmers. Farmers are cash constrained, especially at harvest time, and that limits their ability to invest in FL-RS such as hermetic bags and threshing or storage services at the time these investments are most needed. Farmers are hesitant to secure credit from credit institutions, such as microfinance institutions, not only because they are not sure of the return on investment of the FL-RS and the quality of the product but also due to their inability to generate cash from the sales of produce because they lack access to markets. This lack of market access further exacerbates their financial instability, creating a cycle of limited investment in production and low productivity. To address these issues, a multifaceted approach involving improved access to knowledge and incentives to adopt new technology and enhanced market linkages are essential.

6.3.1.2 Agricultural MSMEs barriers to FL-RS adoption

The use of FL-RS to be operated by Agricultural MSMEs including youth groups and cooperatives, is limited by the lack of proven business cases (capacity utilization, cost of operation, level of service fee) but also due to their limited access to loan facilities because they lack collateral, a credit history, and have limited investment readiness (insufficient records of transactions and business operations).

6.3.1.3 Financial Institutions' barriers to supply agricultural solutions

Financial institutions consider the agricultural sector as high-risk, due to the inherently unpredictable nature of agricultural profitability, influenced by factors like weather and market volatility. The high risk and cost of the agricultural sector, results in banks charging high interest rates over short tenors, which put financial products beyond the reach of Agricultural MSMEs or add to their existing financial burdens. There is a notable lack of financial products tailored to the unique needs

of agricultural value chains, which should ideally account for seasonality, climate risk, and the extended lead times between production, off-taking and selling to end consumers.

6.3.2 Overview of key financing products that currently serve farmers in Uganda

To address the challenges associated with access to and supply of affordable financing, several key initiatives have been undertaken in recent years to reduce the costs associated with agricultural solutions in Uganda. These initiatives encompass a variety of interventions and have had varying degrees of success and impact.

Government – led initiatives implemented in Uganda in the recent years include but not limited to:

The Agriculture Cluster Development Project (ACDP)

Matching grant scheme to enhance post-harvest handling capabilities, such as storage facilities, equipment, tarpaulins, and milling machines. This initiative, implemented by the Ministry of Agriculture Animal Industry and Fisheries (MAAIF), involved co-funding arrangements where farmers contributed 33% and the government provided 67%. The project operated through farmer clusters, groups, and faith-based organizations at the community level. The impact included improved storage capacity in 57 districts, enhanced value addition through agro-processing, and better post-harvest handling. However, the uptake is frequently hindered by limited farmer organizations, insufficient co-funding capacity among some farmers, inadequate training, and the capital-intensive nature of the interventions.

The Agriculture Credit Facility (ACF)

Credit Facility to facilitate the acquisition of inputs and technology, such as storage facilities and processors, through financial loans at a low-interest rate of 12%. This government-backed initiative implemented by the Bank of Uganda (BOU) allowed farmers to access these loans via Participating Financial Institutions (PFIs). The outcomes included better access to warehouses, improved agro-processing capabilities, and reduced post-harvest losses. Despite these benefits, challenges included PFIs' preference for their own products, a lack of awareness among farmers, stringent bank procedures, collateral issues, and poor record-keeping, particularly among smallholder farmers.

The Parish Development Model

Provides access to inputs and equipment purchases through cooperatives and enterprise groups, targeting farmers at the parish level with a provision of one million shillings per household. This government initiative has significantly increased funding access for many farmers. However, it faced obstacles such as lengthy procedures, limited funds, and a negative mindset towards government projects, especially among households classified under the 39% of the poorest in Uganda.

Among the international organisations (donor-led initiatives) implemented in Uganda in the recent years, the most significant ones included:

World Food Program's initiative

Initiative that provides hermetic bags and polythene plastics. The initiative initially improved shelf life and income for farmers, but the high costs, limited awareness, and a lack of supporting financial institutions posed significant barriers.

The Soil and Land Management Program

Focus on climate-smart agriculture, providing tarpaulins, hermetic bags, and silos at subsidized rates. Implemented by MAAIF and UNDP, this programme led to minimal losses due to pests, prolonged shelf life, and increased profits. However, the program's conclusion and high costs restricted its continued impact.

As for the financing schemes and initiatives, managed by the NGOs and private sector in Uganda, the following were highlighted by the stakeholders during the consultations:

One Acre Fund Microfinance Programme

Tailored inputs and post-harvest handling equipment with flexible repayment terms aligned with harvesting cycles, facilitated through Village Based Associations. The programme led to increased knowledge of Good Agricultural Practices (GAP) and access to collateral loans. However, limited awareness restricted its broader adoption.

Agro-Ways Limited initiative focused on community maize shellers

Offers motorized maize shellers and tarpaulins, which improved grain quality and reduced labour costs at the household level. Despite these benefits, the high cost of procurement and maintenance, coupled with a lack of financing options for the private sector, limited the intervention's broader us.

Agricultural insurance schemes

Backed by both government and private companies, these schemes insure against pests, diseases, and adverse weather conditions, compensating farmers for potential harvest losses. This enabled farmers to recover their investments despite calamities. Nonetheless, a pervasive fear of investment, particularly due to unpredictable conditions, limited the widespread adoption of agricultural insurance.

These initiatives have collectively contributed to reducing the costs of agricultural solutions in Uganda. However, agricultural financing in Uganda is still evolving with a need for specific financing products tailored to meet the diverse needs of farmers. The key to maximizing the impact of these financing options lies in improving accessibility, affordability, and farmer awareness, alongside robust risk management strategies.

To remove financial barriers in the agricultural sector in Uganda, several strategic actions could be undertaken. Enhancing training on finance accessibility and management is essential to empower farmers with the knowledge needed to navigate financial systems effectively. Strengthening farmer institutions and encouraging them to operate in clusters can foster collaboration and resource sharing, while promoting supply contracts can provide farmers with more stable and predictable income streams.

Leveraging village savings and loan associations can increase access to low-interest and collateral-free loans, which are critical for smallholder farmers. Promoting common user facilities, such as community equipment and resources, can reduce individual costs and improve efficiency. Supporting farmer entities within key value chains can drive specialization and economies of scale. Empowering cooperatives to obtain favourable financial packages for their members can enhance their collective bargaining power and financial stability.

Reducing high interest rates imposed on agricultural financing agencies is crucial to ensure that these costs are not passed down to the farmers. Creating awareness among farmers about available agricultural financial solutions can enable them to make informed decisions. Provision of low-interest agricultural loans by financial institutions, possibly subsidized by the government, can alleviate the financial burden on farmers.

6.3.3 Suppliers of financial products and services

Across the RE-GAIN focus countries, AGRA has secured letters of interest (LoI) with several financial institutions that intend to increase their agricultural portfolio using clear loan targets, as part of RE-GAIN's overarching strategy. AGRA and the banks have agreed to collaborate to develop the agricultural finance sector through mutually reinforcing opportunities and products.

RE-GAIN programme provides an opportunity where AGRA will conclude agreements with financial institution partners, whereby grants will be used to offset interest rate charges that would normally be paid by farmers, thus enabling smallholder farmers to access loans for working capital, facilitating transactions and financial flows between manufacturers and traders of FL-RS.

The following financial institutions have been identified in Uganda as potential partners:

Table 6-1 Potential financial partner institutions considered for RE-GAIN programme in Uganda

Financial partner	Comment
Agricultural Credit Facility (ACF)	Established by the Government of Uganda in partnership with commercial banks, microfinance deposit-taking institutions, and other financial entities, ACF offers loans to farmers without the need for traditional collateral. This facility has been designed to improve access to credit by accepting alternative forms of collateral, such as chattel mortgages and cash flow-based financing
Uganda Development Bank (UDB)	UDB has launched a Fintech solution, AgriConnect, targeting smallholder farmers with digital loans. This initiative aims to reach 18 000 farmers at full scale, providing them with financial support to increase production and improve food security
Stanbic Bank	Has LoI signed with AGRA, interested in the participation in the RE-GAIN Programme Stanbic Bank has specific agricultural finance products aimed at boosting the agricultural sector. They provide loans for purchasing farm equipment, inputs, and working capital for agricultural activities. Stanbic Bank also supports farmers through capacity-building initiatives and financial advisory services
Dfcu Bank	In partnership with Mastercard and Rabo Partnerships, dfcu Bank provides the Farm Pass platform, which enhances market and credit access for smallholder farmers. This initiative aims to register 1.5 million farmers over five years, promoting financial inclusion and sustainable livelihoods through digital tools
Financial Sector Deepening (FSD) Uganda	FSD Uganda (Financial Sector Deepening Uganda) is an organization dedicated to increasing access to financial services for all Ugandans, with a strong focus on underserved populations including farmers. FSD Uganda partners with various stakeholders to develop innovative solutions that enhance financial inclusion and support agricultural financing. FSD Uganda works on various projects to support financial inclusion, such as developing financial technology solutions, providing financial literacy programs, and facilitating partnerships that promote digital financial services.
Centenary Bank	Centenary Bank is one of the leading banks in Uganda focusing on agricultural finance. They offer various loan products designed for farmers, which helps farmers invest in crop and livestock production. The bank also provides financial literacy programs to enhance farmers' knowledge and management skills

The selection of the ideal partner for the deployment of the financial models will follow the eligibility criteria outlined in section 6.4 for the specific models proposed to be used in the RE-GAIN programme.

6.4 RE-GAIN FINANCING MECHANISMS TO ENHANCE ACCESS TO FOOD LOSS REDUCING SOLUTIONS

The approach taken in the financial model design is focused on strategically using grants to catalyse the development of the market for food loss reducing solutions (FL-RS). These financial mechanisms are designed to address the current market dynamics and challenges faced by smallholder farmers and agricultural MSMEs. The mechanisms do this by enhancing the supply and affordability of FL-RS, thus creating a self-sustaining market and reducing the need for continued programme support.

Despite the potential benefits these models offer, there are several challenges that need to be addressed to ensure effective access and leveraging of FL-RS through financing. One of the primary challenges in accessing FL-RS is the high initial cost of these solutions. Smallholder farmers and agricultural MSMEs often operate with limited capital, making it difficult for them to invest in new technologies and equipment without substantial financial support. This high-cost barrier discourages adoption and limits market penetration. Another significant challenge is the lack of financial products tailored specifically to the agricultural sector. Many financial institutions are hesitant to develop and offer products for smallholder farmers and MSMEs due to perceived high risks and low profitability. Consequently, there is a scarcity of suitable financing options that can support the acquisition and implementation of FL-RS. Smallholder farmers and MSMEs often face difficulties in accessing credit due to stringent requirements set by financial institutions. These requirements typically include collateral, credit history, and other financial credentials that many small-scale agricultural enterprises lack. Without access to credit, these enterprises cannot afford to invest in FL-RS, hampering efforts to reduce food loss.

The effectiveness of FL-RS depends on the quality and appropriateness of the equipment for the local context. Manufacturers need to demonstrate innovation and reliability, but logistical challenges in distribution and maintenance can hinder the uptake of these solutions. Smallholder farmers and MSMEs require assurance that the products will be effectively distributed and maintained, which often involves local partnerships and training programs that are not always readily available. Financial institutions participating in the programme must have robust risk management frameworks to support the sustainability of financial models. However, the agricultural sector is inherently risky due to factors such as weather variability, market fluctuations, and pest outbreaks. These risks need to be adequately managed and mitigated to ensure the viability of FL-RS financing mechanisms.

Activities include interventions at the smallholder and youth group/co-operative levels, improving market linkages, and awareness creation to incentivize adoption of FL-RS. By leveraging partnerships, these models aim to share risks and incentivize market development. Manufacturers must meet specific eligibility criteria, demonstrating innovation and reliability, while financial institutions are required to develop inclusive financial products tailored to the agricultural sector. The programme also includes pathways for MSMEs to access FL-RS through input packages and prefinancing partnership arrangements. Conditional procurement and smart grants will reduce the cost and risk of providing loans to Agricultural MSMEs, aiming to create a self-sustaining market and reduce food loss.The models developed to enhance adoption and uptake of FL-RS consists of (1) conditional procurement for smallholder farmers to reduce the cost of hermetic technology and drying sheets and (2) smart grants to reduce the cost and risk of providing loans to Agricultural MSME buying FL-R equipment and storage solutions.

6.4.1 Solutions for smallholder farmers (part of activity 2.2.1)

Model 1 encourages the local provision of FL-RS interventions by employing conditional procurements to subsidize interventions at the smallholder farmer level, termed 'smart-subsidies.' Essentially, this model allows agro-dealers to offer FL-

RS to smallholder farmers at a lower cost by using GCF funds to purchase one item for every two items bought and sold by an agro-dealer, passing the subsidy as a discount on the purchase price to the smallholder farmers:

- to boost production and manufacturing capacity by placing pre-emptive orders of FL-RS while managing risk by conditionally releasing funds to the manufacturer; and
- to lower the cost of interventions at the smallholder farmer level, thereby increasing profitability, driving additional demand, and promoting knowledge sharing about the benefits of these interventions.

An overview of Model 1 is presented in Figure 6-1, with more detailed descriptions of each step in the text that follows.

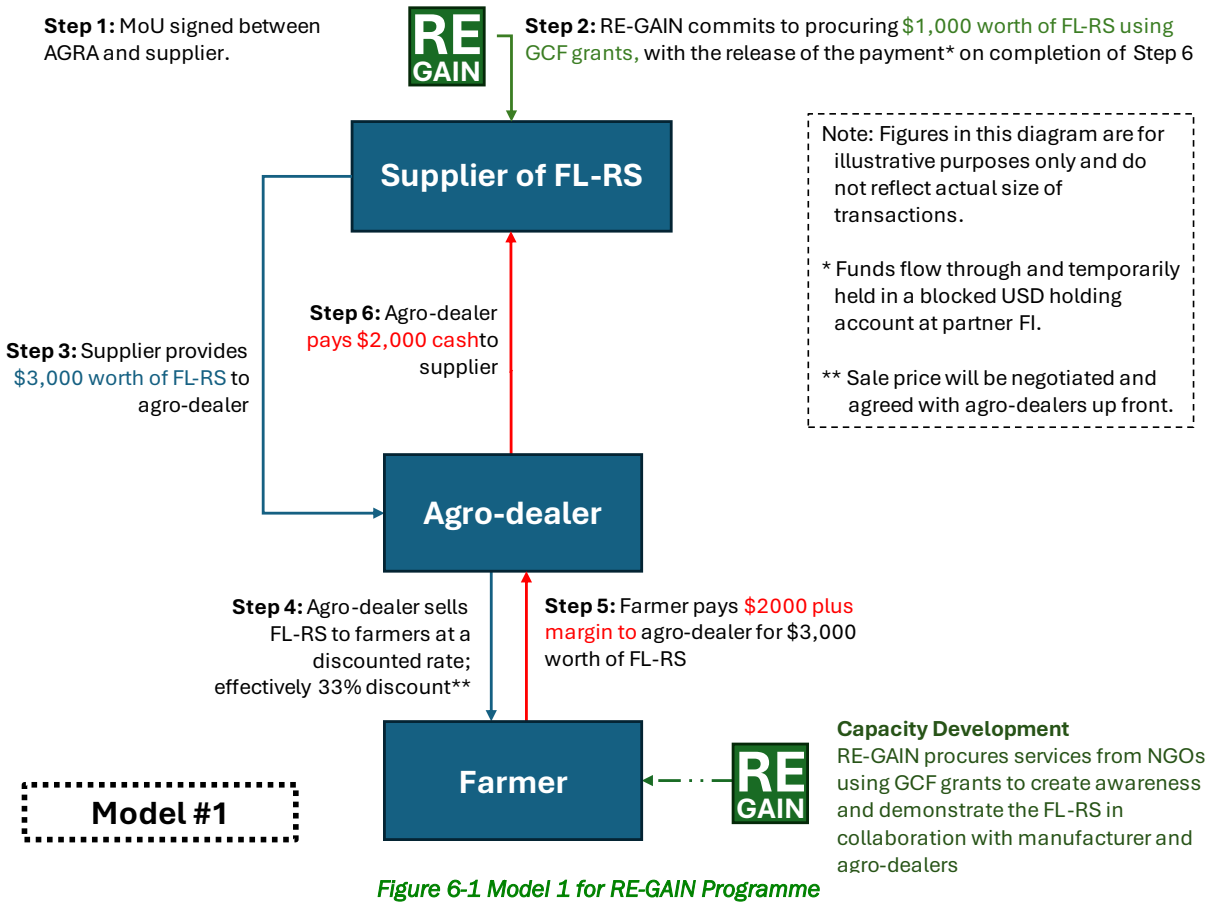

Figure 6-1 Model 1 for RE-GAIN Programme

The implementation of Financial Model 1 within the RE-GAIN programme begins with a facilitation process where AGRA enters into a memorandum of understanding with a supplier. Each supplier will act through its network of agro-dealers in regions where eligible smallholder farmers are located. This agreement sets out the details of the smart subsidy provided by RE-GAIN and the conditions on final sale price offered to the smallholder farmers. This initial step ensures that the eligibility criteria for the subsidies are clearly communicated to the agro-dealers, guaranteeing that the benefits reach the intended target groups.

The next step involves RE-GAIN placing an order for the FL-RS and depositing the value of the order into a holding account. This deposit remains in the holding account until the completion of subsequent steps. The supplier then provides three units to the participating agro-dealers for every one unit procured by RE-GAIN. Depending on the terms of the agreement, agro-dealers either pay for the two non-subsidized units upon delivery or receive them on credit.

Following this arrangement, the agro-dealers offer the FL-RS to smallholder farmers at a discounted rate, effectively transferring the full value of the smart subsidy provided through GCF support. The agro-dealers keep detailed records of the buyers of the subsidized goods, including a limit on how many units each person can purchase to prevent resale and maintain the demonstration goal. This monitoring allows RE-GAIN to ensure the benefits are reaching the target groups and achieving the intended impact.

Smallholder farmers then buy the FL-RS at the discounted rate. The agro-dealers subsequently makes payment to the manufacturer for two units for every one unit of the initial procurement from RE-GAIN (if not already paid on delivery). In cases where an FI is not involved, this payment and a corresponding report trigger the release of the smart subsidy payment from RE-GAIN to the supplier. If an FI was involved, the release of the smart subsidy depends on the repayment of the loan.

Suppliers, agro-dealers, or farmers requiring additional financing for their role in the system can seek support from local financial institutions available in all target countries. For instance, if a supplier needs extra working capital or capital investment to meet increased FL-RS demand, they can arrange a loan with a financial institution to address liquidity requirements for providing FL-RS. Although AGRA may offer guidance to suppliers or agro-dealers on such matters, the agreements themselves will fall outside the scope of the RE-GAIN Programme and will not involve AGRA. The orders placed through RE-GAIN will help mitigate the financial institution's risk in providing loans to suppliers. However, no RE-GAIN Programme funds will be used to lend to suppliers or make payments to financial institutions.

This model benefits all parties involved, with the manufacturer receiving full payment for the FL-RS, the agro-dealer earning income from their markup, and the farmers acquiring FL-RS at a discounted rate. The established market will allow manufacturers to increase production with reduced risk, ultimately lowering the cost of FL-RS in the local market and enabling the smart subsidies to be phased out over time.

The selection of the specific partners AGRA will engage with in the deployment of this model follows the eligibility criteria below:

6.4.1.1 Eligibility Criteria for Suppliers of FL-RS for Individual Farmers

These partners will be selected in the RE-GAIN programme's target countries based on the criteria below:

- Legal capacity to operate: Registration (and ability to produce registration certificate) as a sole trader, partnership, franchise, cooperative, or limited liability company in good order with the local tax authorities
- If operating as an importer, evidence of compliance with import permits
- If appropriate, demonstrated compliance with any Environmental standards or requirements to obtain licences or environmental impact assessments, reports or management plans as required by local laws
- Proof of VAT registration
- Preferably a track record of producing and selling FL-RS as defined as part of the RE-GAIN programme that is approved by the national authorities
- Evidence of record keeping, including financial records;
- Willingness and financial capacity to expand the production levels and distribution network (agrodealers, cooperatives, development projects,) for the FL-RS
- Willingness and financial and human capacity to develop and deploy (subsidized) marketing efforts to enhance uptake of the FL-RS among small scale producers
- Presence in the target regions in the selected countries for the programme;
  Preferably engaging in the provision of solutions for smallholder farmers

6.4.1.2 Eligibility Criteria for Agricultural Traders, Processors, and Agrodealers

These partners will be selected in the RE-GAIN programme's target countries based on the criteria below:

- Legal capacity to operate: Registration (and ability to produce registration certificate) as a sole trader, partnership, franchise, cooperative, or limited liability company in good order with the local tax authorities;
- If operating as an importer, evidence of compliance with import permits;
- If appropriate, demonstrated compliance with any Environmental standards or requirements to obtain licences or environmental impact assessments, reports or management plans as required by local laws;
- Proof of VAT registration;
- Preferably a track record of stocking and selling FL-RS as defined as part of the RE-GAIN programme preferably of the selected manufacturer or importer;
- Evidence of record keeping, including financial records;
- Willingness and financial capacity to stock hermetic technology at the right time (harvest);
- Presence in the target regions in the selected countries for the programme;
- Preferably engaging in the provision of additional services to small scale producers like moisture meters, training, credit and after sales services (aggregation, access to markets).

6.4.1.3 Eligibility Criteria for Smallholder Farmers and Communities

- Smallholder farmers in specific or selected project geographical location with land sizes of between 0 – 2.5 hectares;
- Smallholder farmers (as defined above) that growing relevant crops (usually staples crops);
- Smallholder farmers that are members of local farmer groups in the targeted geographical areas;
- Smallholder farmers with limited access to farming inputs;
- Smallholder farmers with limited level of access to extension services;
- Smallholders that are below the local poverty line or that are food insecure;
- Farmers selected by local community and/or government leadership as priority and or vulnerable farmers (these usually include productive farmers that serve as model farmers, youth, women, special/marginalised groups)

6.4.2 Solutions for Agricultural MSMEs

The second financial model is specifically targeted at assisting Agricultural MSMEs to invest in higher value items "FL-RS (equipment and storage), with prioritisation given to vulnerable groups, by employing grants to enable acquisitions.

The primary objectives of Model 2 are twofold:

- Enhancing Creditworthiness: By leveraging repurchase assurances from suppliers, the model aims to reduce the loss given default, thereby enhancing the creditworthiness of the youth groups and cooperatives involved.
- Reducing borrowing costs: Through a combination of the lowered credit risk (as per above) and subsidies on the purchase price. The structure will ensure higher value FL-RS become more affordable and thus accessible to youth groups who provide services to smallholder farmers.

At the core of Model 2 is the engagement of local youth groups, poised to act as service providers for FL-RS, requiring high-cost equipment that can service multiple farmers. This includes harvesting machinery, mechanical multi-crop threshers and shellers (preferably solar-powered), moisture meters, and communal storage structures. The establishment of these service

operations will be supported through business development initiatives, ensuring that youth groups have a solid foundation to provide reliable services. This approach leverages several key concepts to achieve the targeted benefits:

- **Collectivism:** By pooling resources, smallholder farmers benefit from economies of scale through cost sharing and increased bargaining power with off-takers, promoting further profitability and additional demand for FL-RS.
- **Post-harvest Handling:** Enhancing the quality and quantity of agricultural produce allows smallholder farmers to capture more value, thereby increasing their incomes.
- **Inclusion of Financiers:** Engaging financial institutions will unlock access to finance in a traditionally underserved market. The structure aims to reduce credit risk by providing a partial subsidy, which will lower borrowing costs due to the smaller loan size and reduced interest payments.

The concessional support under this model is primarily aimed at youth groups as a means of fostering livelihood development for these vulnerable community members. However, when paired with business development assistance, the RE-GAIN programme enables youth groups to structure their service fees to reflect the actual (discounted) cost of the equipment. This approach allows them to offer services at fair rates, thereby indirectly transferring the benefits of the concessional support to the farmers utilizing these services.

An overview of Model 2 is presented in who will enter into a separate loan agreement to which AGRA will not be a party.

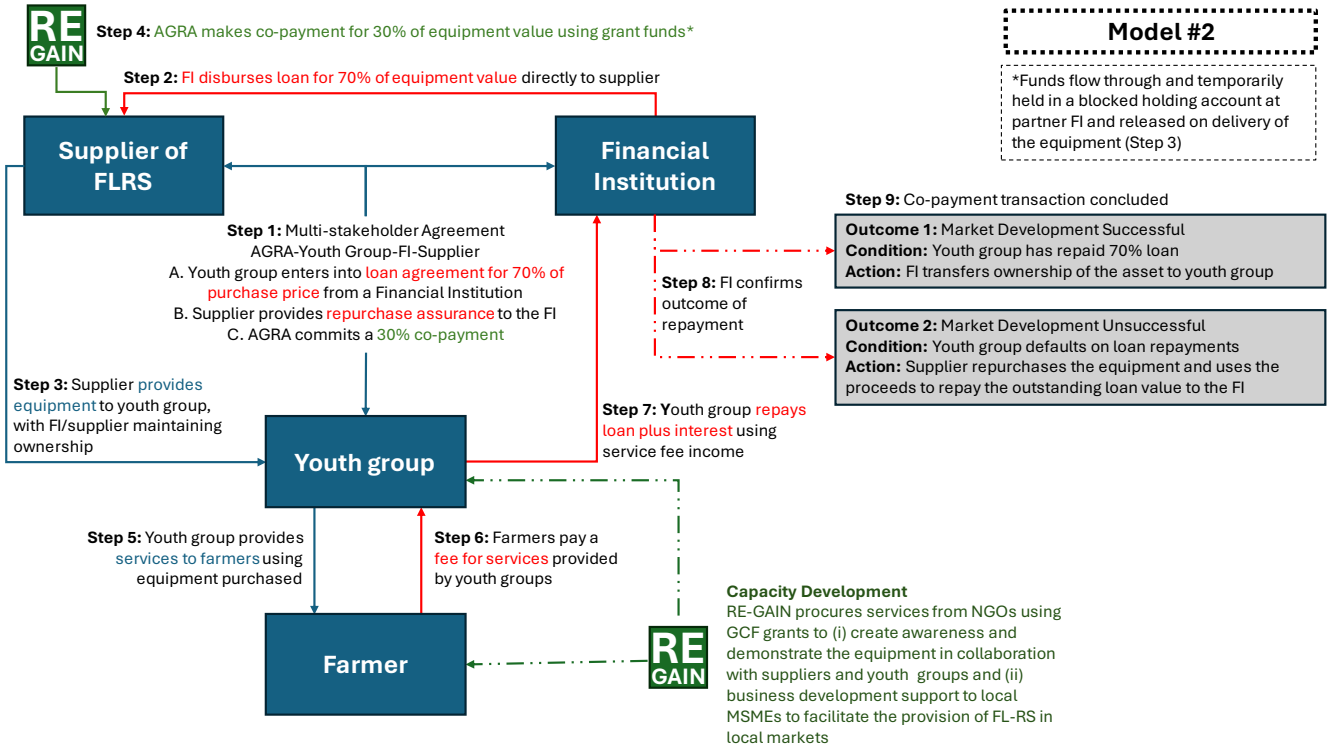

Figure 6-2, with detailed descriptions of each step in the following text. While RE-GAIN will facilitate the establishment of the entire process, its active involvement beyond Step 4, with ownership of Steps 5-9 transitioning to the three partners: youth groups, suppliers, and financial institutions who will enter into a separate loan agreement to which AGRA will not be a party.

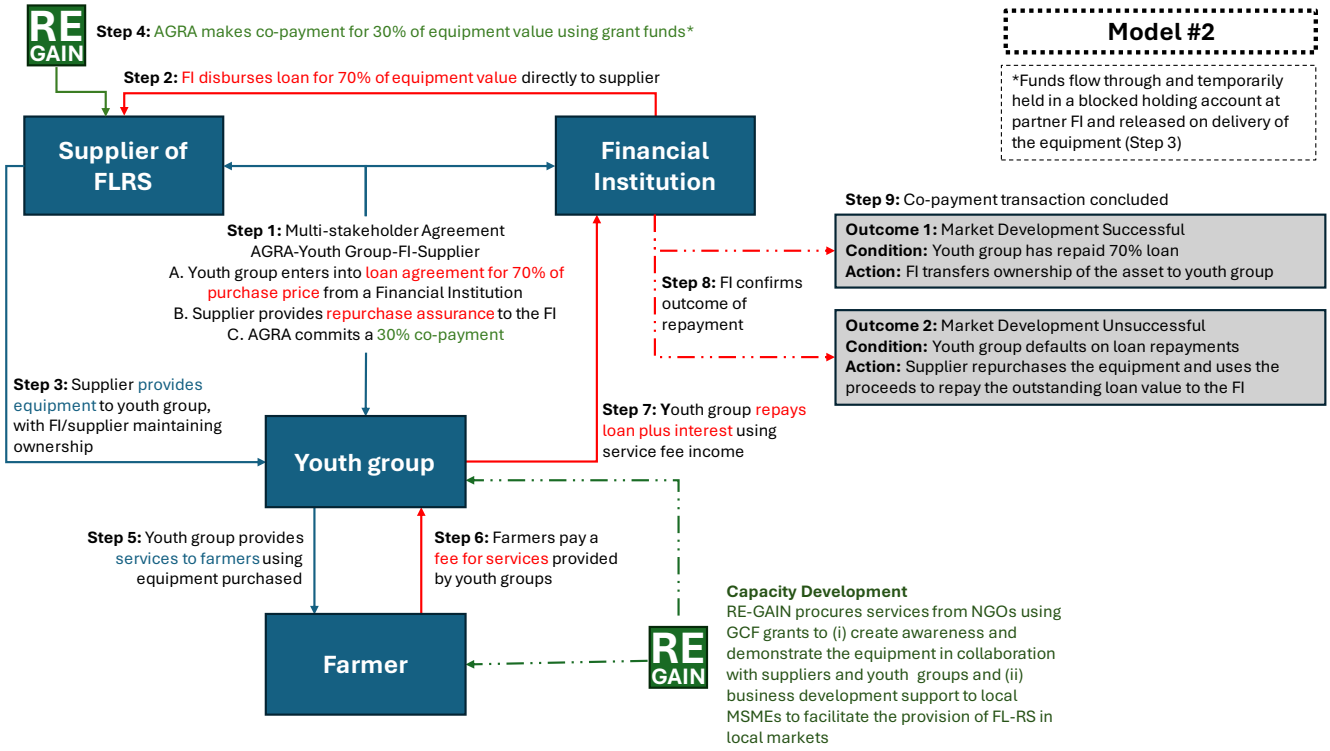

Figure 6-2 Model 2 for RE-GAIN programme

RE-GAIN programme will facilitate the initiation of collaborations between youth groups, suppliers, and financial institutions (FIs). This collaborative effort will be formalized through the signing of a multi-stakeholder agreement. According to this agreement, AGRAcommits to an upfront co-payment covering 30% of the purchase price for the specified equipment. This commitment is contingent upon the youth group agreeing to cover the remaining 70% of the cost. To facilitate this payment, the youth group will secure a loan from the partner FI, while the supplier will provide a repurchase assurance, thus distributing the financial risk between the supplier and the FI. RE-GAIN will oversee the negotiations, ensuring that all aspects of the agreement align with the established eligibility criteria.

Once the multi-stakeholder agreement is in place, the FI will transfer the 70% down-payment directly into the supplier's account on behalf of the youth group. This transaction will initiate the next steps. Concurrently, the remaining 30% co-payment will be deposited into a blocked USD holding account, where it will remain until the equipment is delivered, at which point its release will be triggered.

Upon receiving the 70% payment from the FI, the supplier is obligated to deliver the equipment to the youth group. Following the delivery, the supplier will report the successful receipt of the equipment to AGRA's RE-GAIN PIU.

Upon receipt of the delivery report from the supplier, RE-GAIN will release the 30% co-payment from the holding account to the supplier, thereby completing the initial purchase agreement. At this juncture, the youth group will assume control over the use of the equipment. However, the ownership of the assets will remain with the supplier or the FI, depending on the terms agreed upon during the initial negotiations.

With the equipment now in their possession, the youth group will commence providing FL-RS services to local farmers. To ensure the successful operation of the service enterprise, capacitation support will be provided, ensuring that the youth groups are adequately trained and capacitated to offer reliable and efficient service.

The smallholder farmers will pay the youth group for the FL-RS service, with the youth group collecting income from multiple farmers, thereby distributing the cost of the equipment across multiple beneficiaries. The youth groups will use the income from the services to make repayments to the FI on the loan, covering the cost of the loan and the agreed interest. The upfront co-payment through RE-GAIN reduces the repayment burden on youth groups compared to a scenario where a 100% loan would have been required, thereby decreasing the loan loss given default.

At the end of the agreed loan period, the FI will conclude the transaction and report on the outcome of the repayment. The conclusion of the transaction will lead to one of two possible outcomes:

- In the first scenario, market development was successful, indicated by the youth group operating an FL-RS service and enabling the full repayment of the loan. Under this outcome, the ownership of the asset will be formally transferred to the youth group, allowing them to continue offering the service beyond the initial agreement, without the costs of servicing the loan.
- In the second scenario, market development was unsuccessful, indicated by the failure of the youth group to make the required repayments on the loan. In this case, the supplier's repurchase assurance is triggered, through which the supplier buys back the asset (accounting for depreciation). The value of the repurchase will first go towards the repayment of any outstanding loan amount and any associated transaction fees. Should the repurchase value exceed the outstanding loan amount, any remaining value after transaction fees will be transferred back to the youth group to compensate for any payments made before default.

Model variations may be introduced depending on the local context and nature of FL-RS. In all cases, GCF grants will be used to make a co-payment on the equipment on behalf of the beneficiary (youth group or MSME), thereby reducing the financial burden of the transaction and de-risking the transaction for the suppliers or FIs involved in the agreement.

The selection of the specific partners AGRA will engage with in the deployment of this model follows the eligibility criteria below:

6.4.2.1 Eligibility Criteria for Supplier FL-RS for Equipment

These partners will be selected in the RE-GAIN programme's target countries based on the criteria below:

- Legal capacity to operate: Registration (and ability to produce registration certificate) as a sole trader, partnership, franchise, cooperative, or limited liability company in good order with the local tax authorities
- If operating as an importer, evidence of compliance with import permits
- If appropriate, demonstrated compliance with any Environmental standards or requirements to obtain licences or environmental impact assessments, reports or management plans as required by local laws
- Proof of VAT registration
- Preferably a track record of producing and selling FL-RS as defined as part of the RE-GAIN programme that is approved by the national authorities
- Evidence of record keeping, including financial records;
- Willingness and financial capacity to expand the production levels and distribution network (agrodealers, cooperatives, development projects,) for the FL-RS
- Willingness and financial and human capacity to develop and deploy (subsidized) marketing efforts to enhance uptake of the FL-RS among small scale producers
- Presence in the target regions in the selected countries for the programme;

- Preferably engaging in the provision of solutions for smallholder farmers

6.4.2.2 Eligibility criteria for financial institutions

These partners will be selected competitively in the RE-GAIN programme's target countries based on the criteria below:

- Financial institutions must demonstrate they are licensed, regulated and supervised by the relevant authorities (Central Bank, MFI regulatory body, cooperative agency) and in compliance with any prudential liquidity requirements
- Experience and willingness to offer asset financing facilities of between USD 1.000 and USD 10.000 to equipment buyers and/or operators
- Willingness and ability to engage with Agricultural MSMEs or cooperatives and other key actors in the value chains; Willingness to open an escrow account in AGRA's name at no/low cost and interest rate offered on the AGRA deposit
- Preferable presence (branch or agents) in the regions where the programme will be implemented

6.4.2.3 Eligibility criteria for Youth Groups, MSMEs and Cooperative

These partners will be selected in the RE-GAIN programme's target countries based on the criteria below:

- Registration certificate if formally required under national laws;
- Copy of constitution, and full list of members and officials;
- Preferably a track record (based on physical records) as a service provider to small scale producers (can be in extension, aggregation of produce, selling of inputs or provision of mechanized services);
- Preferably presence in the target regions in the selected countries for the programme and qualified staff or members that have experience in operating, repairing and servicing the machinery;
- Willingness and ability to buy machinery for the purpose of renting it out to small scale producers;
- Willingness and financial capacity to develop and deploy marketing efforts to enhance uptake of the FL-RS services among farmers;
- Preference will be given to women and youth-led MSMEs;
- Preference will be given to those already engaging with business planning activities

6.5 MARKET OF PROVIDERS FOR AWARENESS RAISING AND CAPACITY BUILDING

Awareness raising and capacity building covered by the Component 1 or RE-GAIN Programme requires experienced partners in awareness campaigns and smallholder training. AGRA has historically worked in Uganda leveraging village-based advisors (VBA). The goal is that this component of the programme will be implemented by working with lead farmers, preferably with young ones, as VBAs. Leveraging this network, implementation will include demonstrations (mother-demos) with local agro-suppliers, that can help VBAs and locally-led cooperatives or other organisation of farmers with the opportunity to start viable local agro-services.

Beyond leveraging AGRA's current VBA network in the country, the RE-GAIN programme can also work closely with additional partners to implement these extension services in Uganda. The Ministry of Agriculture, Animal Husbandry and Fisheries (MAAIF) and National Agricultural Research Organisation (NARO) will be a key partners, as these organisations operate extension services and several smallholder-oriented projects. The MAAIF has embarked on an E-Extension Service, which can be used for the awareness campaign as well as for disseminating technical FL-RS training messages.

Several other major agricultural NGOs and farmers' organizations are actively working to support the agricultural sector through various initiatives and programs. These organizations play a crucial role in enhancing agricultural productivity, promoting sustainable practices, and improving the livelihoods of farmers. Therefore, we recommend involving those agricultural NGOs and farmers' organizations to closely work on the RE-GAIN programme implementation in the area of capacity building and awareness raising. Recommended implementation partners are further shortlisted in Table 6-2.

Table 6-2 Potential implementation partners for implementing the awareness campaign and the capacity building programmes in Uganda

Organization	Description
Ministry of Agriculture, Animal Husbandry and Fisheries (MAAIF)	Agricultural Extension Services: These include interventions/activities by government and NSAs that facilitate the access of farmers, their organizations, and other value chain actors to knowledge, information, and technologies; mediate their interaction with other relevant organizations; and assist them to develop their technical and management capacity in agriculture and family life. The MAAIF E-Extension system showcases agricultural training videos in local languages, Profile information for key stake holders in the agriculture sector, Weather advisory, Crises and Outbreaks information from all over Uganda. https://extension.agriculture.go.ug/
FAO Uganda	FAO works with the Ugandan government and local organizations to improve agricultural practices. Their programs offer training and resources on post-harvest management to reduce food losses and improve food security. The RE-GAIN programme to make a head-start with this cooperation http://www.fao.org/uganda
National Agricultural Research Organisation (NARO)	NARO is a government body responsible for agricultural research in Uganda. They offer training and extension services to farmers, including post-harvest management. Programs: Training programs on post-harvest handling techniques, storage solutions, and pest management. (https://naro.go.ug/)
TechnoServe	A non-profit organization that provides business solutions to poverty by linking farmers to markets, improving their skills, and helping them adopt new technologies. Technoserve offers training in post-harvest handling, storage, and processing to improve quality and reduce losses. (https://www.technoserve.org/)
African Institute for Capacity Development (AICAD)	A regional organization (Kenya, Tanzania, Uganda) that focuses on capacity building in various sectors, including agriculture. AICAD conducts training programs on post-harvest technology and management for farmers and agricultural professionals. (https://www.aicad.or.ke/; https://www.aicad.or.ke/uganda-country-offices/)
Kilimo Trust	A non-profit organization that promotes regional solutions to agricultural challenges in East Africa. Kilimo Trust provides training on value chain development, including post-harvest handling and storage for maize and beans. (https://kilimotrust.org/)

International Institute of Tropical Agriculture (IITA)	A non-profit organization that works to improve livelihoods, enhance food and nutrition security, and increase employment through agricultural development. Provides training on post-harvest technologies, pest management, and value addition for staple crops like maize and beans. (https://www.iita.org/; https://www.iita.org/countries/uganda/)
Integrated Seed Sector Development (ISSD) Uganda	An initiative aimed at improving the seed sector in Uganda, which includes post-harvest handling and quality management. Offers training on post-harvest handling to maintain seed quality and reduce losses. (https://issduganda.org/)
Grameen Foundation	An international organization that works to improve food security and farmer livelihoods through technology and training. The foundation offer mobile-based training and advisory services on post-harvest technologies and best practices. (https://grameenfoundation.org/contact-us/uganda-office)
Uganda National Farmers Federation (UNFFE)	Established in 1992, UNFFE aims to represent farmers' interests at national and international levels. It engages in policy advocacy, capacity building, and various agricultural projects aimed at enhancing farmers' productivity and sustainability
Eastern and Southern Africa Small-scale Farmers' Forum (ESAFF Uganda)	ESAFF Uganda is the largest small-scale farmer-led organization in the country, promoting agroecology and food sovereignty. It focuses on empowering small-scale farmers, particularly women, through advocacy, training, and economic empowerment programs
Young Farmers' Federation of Uganda (UNYFA)	Formed in 2016, UNYFA supports young farmers aged 12 to 39 through capacity building, advocacy, market linkages, and agribusiness training. It operates nationwide with the aim of fostering a sustainable agricultural economy led by the youth
Uganda Sustainable Agricultural Support Organisation (USASO)	USASO is an NGO promoting sustainable agriculture practices, including organic farming. It provides training and support to small-scale farmers to enhance their agricultural productivity and sustainability
World Vision Uganda	World Vision Uganda focus on training farmers in modern and climate-smart agricultural practices, which include improved farming methods and effective post-harvest handling techniques. World Vision also emphasizes economic empowerment by promoting farming as a business. They provide resources and skills necessary for smallholder farmers to maximize their profits and improve their livelihoods. Besides that, they actively involve local communities in participatory activities that support the adoption of best agricultural practices.
Kilimo Trust Uganda	Kilimo Trust is a not-for-profit organization working on agriculture for development across the East Africa community – in Burundi, Kenya, Rwanda, Tanzania and Uganda. Kilimo Trust is a go-to implementing partner for inclusive and sustainable market-led agricultural value chain development in the region. It focuses om agricultural development in Africa, with primary aim to enhance market-led agricultural value chains, ensuring that smallholder farmers and other stakeholders can capitalize on structured national, regional, and international markets for agricultural products.

These organizations play a critical role in advancing Uganda's agricultural sector by providing essential services, advocating for farmers' interests, and implementing programs to enhance productivity and sustainability. For the selection of the specific organisations that AGRA will partner with for the delivery of the extension services, the partner selection will follow the eligibility criteria in the section below, as well as the selection of those receiving the extension services across the value chains.

6.5.1 Eligibility Criteria for Extension Services Recipients

The different training activities will target actors across the agricultural value chain, including smallholder farmers and the communities that they form, agrodealers, food processors, manufacturers of FL-RS, financial service providers, and MSMEs or service providers that act across the value chain. Below is the eligibility criteria across these different groups under the RE-GAIN programme. to be included in extension services.

6.5.1.1 Eligibility Criteria for Smallholder Farmers and Communities (for activity 1.1.1, activity 1.1.2, activity 1.1.6 and activity 1.2.1)

- Smallholder farmers in specific or selected project geographical location with land sizes of between 0 – 2.5 hectares;

- Smallholder farmers (as defined above) that growing relevant crops (usually staples crops);
- Smallholder farmers that are members of local farmer groups in the targeted geographical areas;
- Smallholder farmers with limited access to farming inputs;
- Smallholder farmers with limited or level of access to extension services;
- . Smallholders that are below the local poverty line or that are food insecure;
- Farmers selected by local community and/or government leadership as priority and or vulnerable farmers (these usually include productive farmers that serve as model farmers, youth, women, special/marginalised groups)

6.5.1.2 Eligibility Criteria for Agricultural Traders, Processors, and Agrodealers (for activity 1.1.3 and activity 1.1.7)

These partners will be selected in the RE-GAIN programme's target countries based on the criteria below:

- Legal capacity to operate: Registration (and ability to produce registration certificate) as a sole trader, partnership, franchise, cooperative, or limited liability company in good order with the local tax authorities;
- If operating as an importer, evidence of compliance with import permits;
- If appropriate, demonstrated compliance with any Environmental standards or requirements to obtain licences or environmental impact assessments, reports or management plans as required by local laws;
- Proof of VAT registration;
- Preferably a track record of stocking and selling FL-RS as defined as part of the RE-GAIN programme preferably of the selected manufacturer or importer;
- Evidence of record keeping, including financial recordsAt least 3 years of management accounts preferably audited;
- Willingness and financial capacity to stock hermetic technology at the right time (harvest);
- Presence in the target regions in the selected countries for the programme;
- Preferably engaging in the provision of additional services to small scale producers like moisture meters, training, credit and after sales services (aggregation, access to markets).

6.5.1.3 Eligibility Criteria for Village- Based Advisors (VBAs) (for activity 1.1.4)

The selection process should ensure that the VBA is:

- A resident of the community or resides in the geographical location/area of the target beneficiaries/farmers;
- At least 10th grade education;
- Knowledge of farming, must have at a minimum .05 hectare of farmland
- Existing 'lead farmers' that have been identified in communities by other government or partner programmes
- A member of existing community-based groups (farmer cooperative, farmer groups, nutrition groups youth groups etc)
- Entrepreneurial skills are an advantage
- Where local practices demand, the VBA will be selected or endorsed by local community leaders
- Women and youth will be preferred VBA candidates

6.5.1.4 Eligibility Criteria for Manufacturers of FL-RS (for activity 1.1.5)

These partners will be selected in the RE-GAIN programme's target countries based on the criteria below:

- Legal capacity to operate: Registration (and ability to produce registration certificate) as a sole trader, partnership, franchise, cooperative, or limited liability company in good order with the local tax authorities
- If operating as an importer, evidence of compliance with import permits
- If appropriate, demonstrated compliance with any Environmental standards or requirements to obtain licences or environmental impact assessments, reports or management plans as required by local laws
- Proof of VAT registration
- Preferably a track record of producing and selling FL-RS as defined as part of the RE-GAIN programme (that is approved by the national authorities
- Evidence of record keeping, including financial records Willingness and financial capacity to expand the production levels and distribution network (agrodealers, cooperatives, development projects,) for the FL-RS
- Willingness and financial and human capacity to develop and deploy (subsidized) marketing efforts to enhance uptake of the FL-RS among small scale producers
- Presence in the target regions in the selected countries for the programme;
- Preferably engaging in the provision of solutions for smallholder farmers

- RS

6.5.1.5 MSMEs and Cooperatives (for activity 2.1.1 and activity 2.1.2)

These partners will be selected in the RE-GAIN programme's target countries based on the criteria below:

- Registration certificate if formally required under national laws
- Copy of constitution, and full list of members and officials
- Preferably a track record (based on physical records) as a service provider to small scale producers (can be in extension, aggregation of produce, selling of inputs or provision of mechanized services)
- Preferably in the target regions in the selected countries for the programme and qualified staff or members that have experience in operating, repairing and servicing the machinery
- Willingness and ability to buy machinery for the purpose of renting it out to small scale producers
- Willingness and financial capacity to develop and deploy marketing efforts to enhance uptake of the FL-RS services among farmers
- Preference will be given to women and youth-led MSMEs;
- Preference will be given to those already engaging with business planning activities

6.5.2 Eligibility Criteria for Extension Services Delivery Partners

The potential [programme/implementing] partners are not-for-profit, non-governmental organizations, private sector organizations, regional economic or specialized bodies, government departments with technical expertise and competencies in agrifood systems, policy development, monitoring and implementation, project management, scientific and social research, natural resources management, climate change, training, capacity building, knowledge management and other relevant areas.

6.5.2.1 Fit for Purpose

Institutions/organizations intending to work with AGRA in this area of work must demonstrate that they meet the following requirements to be eligible to receive financing from AGRA:

- Unless specifically stated otherwise in this section, must be registered in the national country with valid registration documents;
- For its stated area of expertise, organization must produce certifications, marks or permits as required by national legislations, demonstrating adherence with relevant codes of practice, industry standards etc
- Organization's primary business activity must be in the stated focal countries;
- Organization must be in a sound financial condition;
- Organization must have sufficient existing capability/capacity to perform as required. AGRA may consider limited funding for capacity building only if the entity's proposal is determined to be of interest to AGRA;
- Organization must have demonstrated favorable past performance record;
- Organization must have accounting systems, procurement practices and corporate integrity/ethics aligned to AGRA systems and values;
- Organization must not have been previously excluded from the eligibility to receive funding from any of AGRA's partners;
- Demonstrate inclusivity and promote sustainability principles in past project activities

6.5.2.2 Technical Competencies

Other key considerations – these will be dependent on the thematic focus of the work being undertaken:

a) Minimum of 5-7 years of demonstrable organization working experience in any/all or a combination of the following systems level areas: Value Chain Development, Sustainable Farming, Seed systems, Fertilizer and Soil health systems, Market and Financial Access systems, MSME development, Agriculture and/or Food systems policy, Climate Change, Natural Resources Management, Extension and Input Distribution systems, and Climate-smart Agriculture in Africa;
b) Demonstrable ability to work with private sector partners and have experience leading/facilitating value chain development, linkage of smallholder farmers to markets, and resilience building initiatives;
c) Experience working with women and youth (and other underserved groups);
d) A team with experience working in smallholder agriculture value chains in Africa; experience in natural resources management, climate change, MSME development and working with national institutions;
e) Present qualified personnel/CV's of key staff proposed
f) Applications should be in line with the RE-GAIN Programme's E&S policy, as further described on Annex 6

AGRA may request additional documentation to be submitted as part of the pre-award process. Organizations are advised that any funds made available are subject to AGRA's accountability and audit requirements.

6.5.2.3 Evaluation Criteria/Scoring Weights

The selection of partners will follow the below scoring criteria, and percentages may vary slightly.

1. Fit-for-Purpose (Governance and management) 20%
2. Technical Ability and past experience 50%
3. Personnel Qualification and others 20%
4. Approach and methodology 10%

6.6 SUPPORTING AN ENABLING ENVIRONMENT FOR FL RS ADOPTION AND UPTAKE

Besides the availability and affordability of FL-RS, building a strong enabling environment remains a critical factor for the success of RE-GAIN programme implementation. The lack of progress in food loss reduction is attributable to several factors, including inadequacies in policy and regulatory frameworks and the general lack of capacity among mandated institutions to drive effective strategies, technologies, practices, and initiatives for post-harvest loss reduction. These barriers can be solved by leveraging activities that can strengthen policy and regulatory frameworks and institutions on post-harvest losses, enhancing the enabling environment in the programme countries to best drive systemic changes in the post-harvest food loss space. This will be addressed through the Component 3 of the Programme and its specific activities, working with mandated government institutions in the areas of focus across the different countries in scope of the programme. The activities include:

1. Examine existing national and sub-national legislation and policies related to food loss reduction, to identify gaps, and inconsistencies and address policy barriers.
2. Support policy and regulatory reforms that change the incentive structure; create an enabling environment to attract investments; and encourage the adoption of best practices on food loss reductions. Specific policy reforms include:
    - Regulated quality-based pricing system as an incentive to invest in loss-reduction technologies and practices;
    - Tax exemption on imports, financial incentives (including subsidies) for local manufacturers of postharvest technologies to make proven technologies more available, accessible, and affordable;
    - Efficient Warehouse Receipt Systems to accelerate the efficient removal of the crop from the farmer into safe centralized storage;
    - Development of national policy and technical regulation for aflatoxin control;
    - Policies and programs that promote science, innovation and the adoption of climate-smart technologies and practices;
    - Develop new legislation to promote compliance with regulatory standards and uptake of interventions to reduce postharvest loss

AGRA will also support legislative bodies and mandated institutions to enact necessary laws and regulations to support the implementation of these policies:

1. Support domestication of existing Regional Postharvest Loss Management Strategies;
2. Support the development of national strategies, policies, and legislation enabling food loss reduction in line with national agrifood system objectives and policy frameworks;
3. Support the development of programmes and initiatives to improve the availability of accessible weather information;
4. Support the development and implementation of national food loss strategies and action plans, ensuring policy coherence and mutual accountability through multistakeholder, intersectoral and inter-ministerial collaboration and coordination to align visions and interests of all stakeholders and sectors;
5. Support the development of collaboration platforms across industry players and key value chain actors, including academia, research centers and innovation hubs to share knowledge and best practices on food loss reduction;

6. Supporting Public-Private Partnerships, that allow for greater collaborations between the government and private sector to invest in innovative postharvest technologies, modern storage facilities and transportation logistics;
7. Strengthen institutional capacity for effective partnership, cooperation, and engagement of postharvest management stakeholders to facilitate the execution of planned interventions

Active involvement and support from government organizations, both central and local, will be crucial. RE-GAIN programme will align with other projects and programmes mentioned in Chapter 2, to leverage synergies, utilize existing laws and policies on FL reduction, smallholder farmer support, and ensure effective and efficient programme management. In all seven countries, RE-GAIN programme will prioritize inclusivity for women, youth, indigenous people (where present), and minority groups, and all value chain actors in the planned activities.

Table 6-3 summarises strategic approach for the RE-GAIN programme for Uganda:

Table 6-3 Systematic approach to creating enabling environment for the success of the RE-GAIN programme

Strategic pillar	Key activities	Expected Outcome
Policy Support and Revision	• **Examine existing national and sub-national legislation and policies:** Review current legislation and policies related to food loss reduction to identify gaps, inconsistencies, and barriers. • **Support policy and regulatory reforms**: Facilitate reforms that change the incentive structure, create an enabling environment for investments, and encourage the adoption of food-loss best practices. Specific policies and regulatory frameworks are described above.	A supportive policy environment that enables the successful implementation of the RE-GAIN programme and widespread adoption of FL-RS solutions.
Legislative Support and Capacity Building	• **Develop national strategies and policies:** Support the creation of strategies and legislation that align food loss reduction efforts with national agrifood system objectives. • **Support Public-Private Partnerships (PPPs):** Promote PPPs to enhance collaboration between government and the private sector, investing in innovative postharvest technologies, modern storage facilities, and transportation logistics. • **Strengthen institutional capacity:** Build capacity for effective partnerships and stakeholder engagement to facilitate the execution of planned interventions.	Advocate for the development of initiatrives and legislation that can strengthen both food-loss reduction activities as well as strehgnten institutions to drive systematic transformation.
Awareness and Communication:	• **Establish platforms for knowledge sharing**: Support the creation of collaboration platforms among industry players, value chain actors, academia, and research centers to share best practices in food loss reduction • **Advocate for distribution of accessible weather information:** Support governments' initiatives to provide more easily accessible weather information, and support campaigns to raise the profile of these initiatives across the different countries	Strong awareness about the impact of increased FL-RS adoption and its impact on food loss reduction, climate change mitigation, and incomes of smallholder farmers
Government Alignment and Synergy Building	• **Actively involve central and local government:** Establish formal partnerships with relevant government bodies at both central and local levels. Facilitate regular meetings and consultations to ensure alignment of the RE-GAIN programme with national and regional development priorities. • **Promote collaboration across sectors**: Facilitate the development and implementation of national food loss strategies and action plans through multistakeholder, intersectoral, and inter-ministerial collaboration. • **Coordinate with other projects to create synergies:** Work closely with other development projects and programmes to identify areas of overlap and collaboration. Develop joint action plans, share resources, and coordinate activities to maximize impact and avoid duplication of efforts.	Strong collaboration with government entities and other programmes, leading to a more cohesive and impactful implementation process.

6.7 CONCLUSIONS ON THE MARKET STUDY

The proposed solutions at the RE-GAIN programme are not unknown in the Ugandan market. However, there are clear challenges and gaps that the programme aims to focus on to tackle by empowering both supply and demand of these solutions, as well as improving the capacity of those using these solutions, alongside with mainstreaming knowledge related to climate resilience in the harvest and post-harvest stages of the selected value chains. Beyond working closely with smallholder farmers, there is also a need to influence and strengthen the enabling environment to reduce food losses.

The proposed RE-GAIN programme leverages what already exists in Uganda when it comes down to harvest and post-harvest food and aims to further strengthen and build the market in the country for harvest and post-harvest solutions, but tackling the challenge from different angles and ultimately strengthening the country's agricultural sector's climate resilience.

7 Conclusion

Food loss is a growing challenge in Uganda, with significant losses within the harvest and post-harvest stages for key crops in the country; maize and beans. As previously discussed, climate change is likely to exacerbate this situation, further impacting the resilience of smallholder farmers involved in these value chains and threatening food security in Uganda. Given the critical role of these crops in the country's economy and overall food supply, food losses have significant implications for the livelihoods of smallholders and the nation's nutrition. Additionally, food losses contribute to emissions and influence land use change dynamics. This context underscores the critical need for a programme like RE-GAIN, which plays a pivotal role in fostering greater climate resilience in Uganda by addressing the key barriers identified during this phased study, as described in the image below:

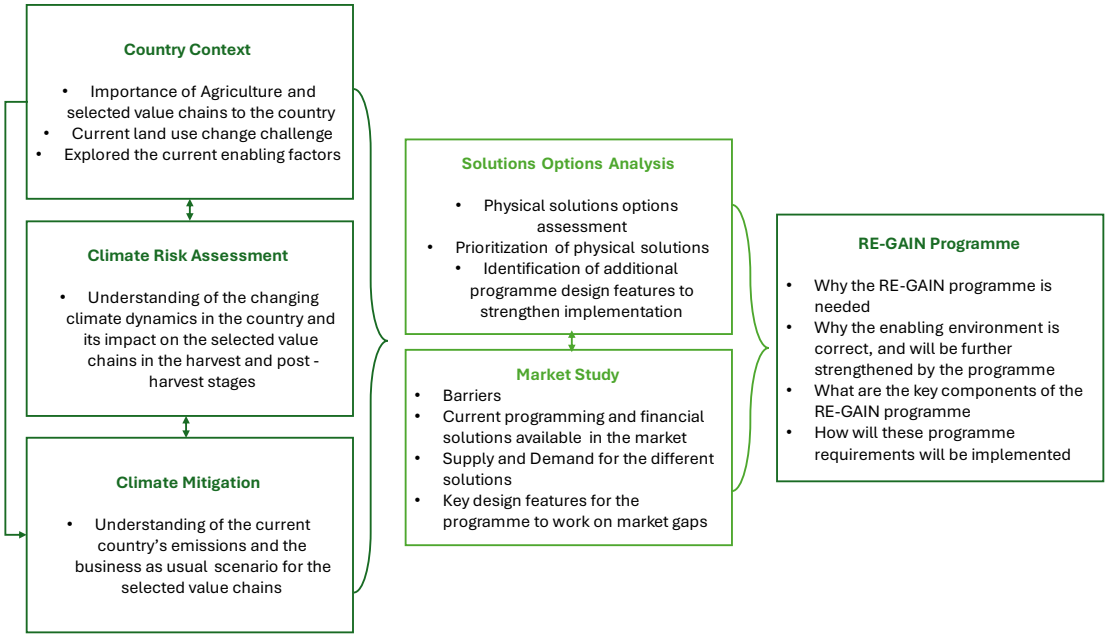

Figure 7-1 Content Summary of Feasibility Study for the RE-GAIN programme

With this in mind, this feasibility study aimed to assess the most viable programme to support smallholder farmers in the harvest and post-harvest stages of the maize and beans value chains within the Ugandan context. Our analysis focused on the country's vulnerability to climate change, the structure of its agriculture sector, its economic profile, and the current food-loss landscape. Uganda is highly vulnerable to the impacts of climate change, which constrain the country's sustainable development ambitions and threaten the lives and livelihoods of vulnerable communities. These findings underscore the necessity of this project.

The identification and analysis of relevant policies in the agricultural and environmental sectors demonstrate that Uganda has a foundational enabling environment for a comprehensive food-loss reduction programme aimed at promoting both the supply and demand of these solutions. However, despite this supportive framework, there is a clear need for a programme like RE-GAIN. Currently, no existing programs specifically focus on simultaneously building climate resilience and addressing harvest and post-harvest food losses. Most initiatives either concentrate solely on enhancing climate resilience in Uganda or focus independently on improving preharvest agricultural production.

Our analysis revealed that the challenges with food-loss solutions and their effective usage are complex and multifaceted. Notably, our market study revealed that the current solutions available are insufficient for smallholders to build their resilience in worsening climate conditions. There are both supply and demand challenges for the physical food-loss solutions in the market, particularly regarding financial accessibility and sufficient availability of high-quality solutions. Additionally, smallholder farmers face capacity challenges in various areas, such as understanding the impact of climate on their harvest and post-harvest activities and leveraging physical solutions to mitigate climate challenges and improve food security. Building on the current enabling environment, the programme will collaborate with various levels of the Ugandan government and the national private sector to further enhance existing frameworks. This includes implementing quality standards and other regulatory policies to enhance the supply and demand of food-loss solutions. These interconnected barriers and challenges underscore the need for a comprehensive programme like RE-GAIN. By addressing these diverse issues, RE-GAIN can significantly reduce food loss and bolster the resilience of smallholder farmers, with a co-benefit of GHG emission reduction.

This study has provided a comprehensive analysis of how climate is impacting harvest and post-harvest activities in Uganda, and highlighted the lack of a unified initiative that can respond to these growing challenges and support Uganda's mitigation initiatives. RE-GAIN offers a solution by reducing food losses across the maize and beans value chains, ultimately benefiting the large population involved in their production and enhancing food security. It facilitates access to physical solutions that bolster smallholders' climate resilience and adaptive capacity, while also providing additional support through extension services that can guarantee the long-lasting impact of the programme. By also focusing on strengthening the enabling environment, RE-GAIN aims to drive systemic changes that promote effective food loss management during harvesting and post-harvesting activities.

Ultimately, this study illustrates how the RE-GAIN programme has been strategically designed to address the challenges of increasing food loss and escalating climate vulnerability in the identified regions. A successfully implemented RE-GAIN programme will provide comprehensive solutions to harvest and post-harvest food loss challenges, resulting in a lasting, transformative impact on Uganda. Over time, this programme will become self-sustaining, significantly improving the resilience and sustainability of the country's agricultural sector.

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