ANNEX 2

Zambia

Maize and Soybeans
Version 4

2024

RE-GAIN: Scaling Solutions for Food Loss in Africa

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ACRONYMS

AGRA	Alliance for a Green Revolution in Africa
APHLIS	African Postharvest Losses Information System
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical (International Centre for Tropical Agriculture)
CLP	Commodity Loss Prevention
CSA	Climate-Smart Agriculture
EARF	Energy Access Relief Facility
FAO	Food and Agriculture Organization
FAS	Foreign Agricultural Service
FL-RS	Food Loss Reduction Solutions
GCF	Green Climate Fund
GDP	Gross Domestic Product
GHG	Greenhouse Gas
ICRF	Infrastructure Climate Resilient Fund
IDH	Sustainable Trade Initiative
IFAD	International Fund for Agricultural Development
IPAD	International Production Assessment Division
IPCC	Intergovernmental Panel on Climate Change
LULC	Land Use and Land Cover
MSME	Micro, Small, and Medium Enterprises
MT	Metric Tonnes
OECD	Organisation for Economic Co-operation and Development
REPP	Renewable Energy Performance Platform

SDG	Sustainable Development Goals
SME	Small and Medium Enterprises
SSA	Sub-Saharan Africa
SSP	Shared Socioeconomic Pathways
UGEAP	Universal Green Energy Access Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
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 Zambia, maize and soybeans play a crucial role in the agricultural sector but suffer from significant post-harvest losses, with maize losses reaching up to 30% (USAID, 2022) and soybeans up to 20% (FAO, 2023). These losses undermine food security and the country's economic stability. The frequent occurrence of droughts and floods further aggravates these food losses, endangering the livelihoods of over 70% of the population who rely on agriculture and posing a serious threat to Zambia's agricultural productivity (International Monetary Fund. African Dept., 2023).

As climate change poses a growing threat and agriculture remains pivotal to Zambia's economy, managing post-harvest food losses in maize and soybean production is critical for socio-economic stability. Agriculture is fundamental to Zambia's economy, supporting rural livelihoods, and employing about 57% of the workforce (The World Bank, n.d.). Smallholder farmers, who manage 85% of the agricultural land, primarily cultivate maize and soybeans, among other crops. Maize is crucial to Zambia's food security, predominantly used for both subsistence and as a staple in the national diet. Soybeans are significant for Zambia, utilized for both local consumption and as a cash crop, and are vital for maintaining soil fertility through crop rotation (Zambia Agribusiness Society, 2019). Agricultural activities are concentrated in three primary agro-climatic regions, featuring distinct growing seasons: the rainy season from November to April, the cool dry season from May to August, and the hot dry season from September to October (Japan Association for International Collaboration of Agriculture and Forestry, 2008). Therefore, considering climate change impacts and implementing appropriate mitigation and adaptation measures for crop production, processing, and subsequent food loss is essential to maintaining Zambia's socio-economic stability.

Despite various national policies and programmatic interventions aimed at supporting climate change adaptation, mitigation, and reducing post-harvest food losses, there is a need for intensified efforts to bolster food security. Zambia has developed several policies and interventions to support climate change adaptation, mitigation, and the management of post-harvest food losses. The 8th National Development Plan (8NDP) emphasizes boosting agricultural productivity, improving access to finance, and enhancing storage and logistics. The Second National Agricultural Policy promotes sustainable agricultural diversification and addresses high post-harvest losses through improved storage and handling practices. The Climate-Smart Agriculture Investment Plan (CSAIP) focuses on sustainable land management, enhancing resilience, and reducing emissions. In addition to these national policies, the Green Climate Fund (GCF) supports projects such as the Strengthening Climate Resilience of Agricultural Livelihoods in Agro-Ecological Regions I and II in Zambia, which aims to enhance the resilience of smallholder farmers through improved access to climate information and sustainable agricultural practices. Other relevant initiatives include the FAO's Post-Harvest Loss Reduction Initiative and the USAID/Prosper Africa/Bechtel Zambia Partnership, which focus on reducing food losses through better storage technologies and farmer training. These policies and programmes predominantly target smallholder farmers across Zambia's primary agro-climatic regions, with a strong emphasis on enhancing infrastructure, capacity building, and market access. While these efforts address key aspects of climate adaptation and mitigation, gaps remain in comprehensive data collection on post-harvest losses, effective implementation of climate-smart practices, and ensuring consistent funding and support for smallholder farmers. Addressing these gaps is crucial to effectively managing the impacts of climate change on agriculture and ensuring food security in Zambia.

A deeper understanding of the climate risks associated with Zambia's agricultural sector is necessary to determine appropriate climate adaptation measures. Zambia faces significant climate risks, including increasing temperatures, erratic rainfall patterns, and extreme weather events such as droughts and floods. These risks predominantly affect the central, southern, and eastern regions, with smallholder farmers being particularly vulnerable. The impacts of these climate risks include reduced crop yields, increased pest infestations, and heightened post-harvest losses, leading to food insecurity and economic instability. Historically, Zambia has experienced variability in rainfall and temperature, with data from 1960 to 2006 showing a trend towards rising temperatures, averaging an increase of approximately 1.3°C, and more frequent extreme weather events. Climate change projections under RCP4.5 and RCP8.5 scenarios indicate that Zambia will continue to face increasing temperatures, with more hot days exceeding 35°C, and a rise in the frequency and intensity of droughts and heavy rainfall events by 2040 (USAID, 2016). These projected trends underscore the urgent need for comprehensive climate adaptation and mitigation strategies in Zambia to safeguard agricultural productivity and food security.

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 patterns lead to reduced yields and increased post-harvest losses. This is evident with the observed climate trend of rising temperatures and more frequent droughts, particularly from 2005 to 2050, which corresponds with the observed decreasing yields. Projections indicate that maize yields will continue to decrease under future climate scenarios, particularly under the SSP5-8.5 scenario (GFDRR, n.d.). Additionally, post-harvest losses are exacerbated by the impacts of climate change which include increased humidity and pest infestations. These losses will negatively affect food security and economic stability, as reduced maize yields will result in lower income for farmers and higher food prices. Managing adaptation measures to stabilize maize yield and reduce post-harvest losses due to climate change is therefore critical for the value chain.

Soybeans are similarly impacted by climate change, with rising temperatures and unpredictable rainfall patterns leading to decreased yields and increased food losses during various post-harvest processes, including handling, drying, and storage. Soybean production has experienced variability in yields due to these climatic conditions, resulting in heightened risks of crop failure. Soybean yields are projected to decrease by approximately 3% under the SSP5-8.5 scenario and potentially increase in certain regions under SSP2-4.5 until 2050 due to climate change impacts such as higher temperatures and changing precipitation patterns (CGIAR, CCAFS, CIAT, 2019). The implication of these climate impacts on soybeans includes reduced productivity and economic losses for farmers. Therefore, implementing climate adaptation measures for the growing and processing of soybeans is 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 Zambia's agricultural sector. Zambia's agricultural sector is marked by the expansion and intensification of land use, with cropland area steadily increasing as the country shifts from subsistence farming to more extensive agricultural practices. This expansion has resulted in significant deforestation, posing a serious threat to biodiversity and contributing to greenhouse gas emissions. In response, there is a growing emphasis on climate-smart agriculture and a shift towards large-scale commercial farming, supported by government policies aimed at boosting agricultural productivity and resilience to climate change (World Bank Group; Government of Zambia, 2019).

Additionally, Zambia's emissions trajectory is concerning, with Agriculture and land-use change, and forestry are the largest emitting sectors at ~22 million tonnes CO2e and ~52 million tonnes CO2e as of 2021, respectively (Climate Watch, n.d.). The country's GHG inventory projects a substantial increase in emissions by 2030 under business-as-usual (BAU) scenarios. Emissions from agricultural sources, such as livestock and rice paddies, are expected to rise to 132.7 $MtCO_2e$ by 2030 (Government of Zambia, 2020). Mitigation of these emissions is critical in the response to climate change.

Of Zambia's emissions contributions, food losses account for a significant proportion, particularly in the maize and soybean value chains. The emissions associated with food loss across the agricultural value chains considered by the RE-GAIN programme for Zambia could amount to approximately 1,321,504 tCO_2e for maize and 316,242 tCO_2e for soybeans by 2032 based on smallholder production values (Porter, Reay, Higgins, & Bomberg, 2016). Without intervention, emissions related to post-harvest losses on smallholder farms in Zambia are expected to increase by between 8% and 21%. Therefore, it is crucial to minimize post-harvest food losses to reduce emissions and support climate change mitigation efforts.

Most post-harvest losses contributing to agricultural emissions in Zambia occur during storage, drying, and threshing processes and are exacerbated by climate change. On-farm post-harvest losses in the maize value chain of up to approximately 13% occur because of inadequate storage facilities, poor drying practices, and pest infestations (APHLIS, n.d.). For soybeans, on-farm post-harvest losses of around 43% occur largely because of inefficient harvesting equipment and poor storage conditions (Nshimyumuremyi, 2023). Non-climatic factors such as limited access to proper storage infrastructure, inadequate training for farmers, and high costs of post-harvest technologies also contribute to food losses in Zambia. Increased temperatures and erratic rainfall due to climate change worsen the already high post-harvest losses of maize and soybeans because of increased moisture and pest proliferation, further threatening food security. Addressing these challenges through effective mitigation and adaptation strategies in post-harvest food loss management is essential to safeguarding Zambia's food security.

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, SME 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 Zambia's maize and soybean 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 Zambia. 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.

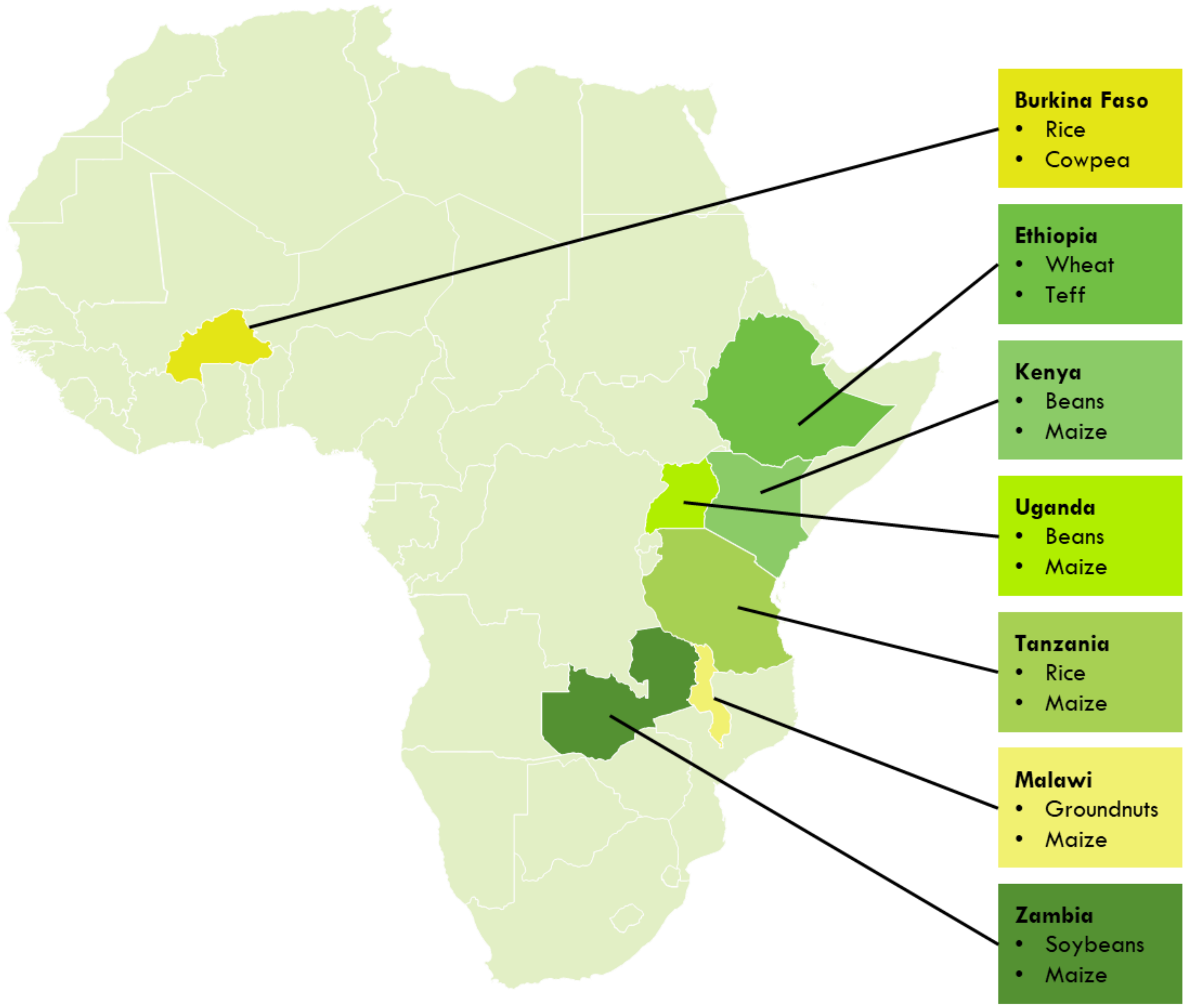


Figure 1-1 Focus Geographies for AGRA (2023-2027)

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

Zambia covers 75 million hectares (752.000 km²), out of which 58% (42 million hectares) is classified as medium to high potential for agriculture production. The country boasts abundant water resources suitable for irrigation, offering significant potential to expand its agricultural output (Ministry of Agriculture of Zambia, 2022). The climate in Zambia mirrors that of many Southern African countries, featuring a rainy season from November to April and a dry season with low humidity from May to November. Average summer temperatures reach around 30°C, while winter temperatures can drop to as low as 5°C

Zambia experiences a tropical climate and can be categorized into three primary agro-climatic zones as depicted in Figure 2-1. Region I is semi-arid, located in the southern, eastern, and western parts of the country, and receives 600-800 mm of rainfall annually. This region mainly comprises smallholder farmers. Region II includes the Central, Southern, Eastern, and Lusaka provinces, where most commercial farming occurs, with annual rainfall of 800-1.000 mm. Region III is a high rainfall area covering the Northern, Luapula, Copperbelt, Northwestern provinces, and parts of the Central province, primarily consisting of smallholder farmers (Independent Evaluation Unit, 2022).

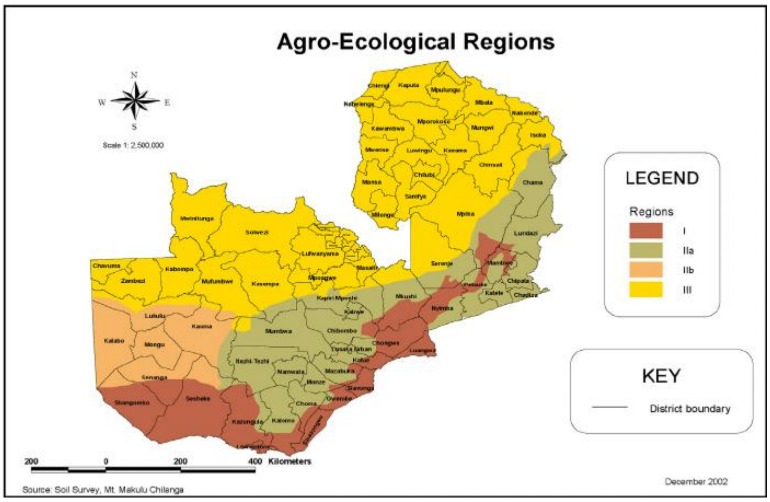


Figure 2-1 - Agro-ecological regions of Zambia

Despite having extensive arable land, transport infrastructure, abundant water, and affordable labour (with agriculture employing more than half of the total labour force), only 15% of Zambia's arable land is under cultivation. The country has a population of approximately 20 million, with around 2.3 million farming households, more than 70% of whom depend on agriculture (International Monetary Fund. African Dept., 2023).

The Zambian agricultural sector includes about 1.6 million smallholder farmers, with over 20% headed by women. Women constitute approximately 65% of the agricultural labour force and are crucial in both production and processing activities (Farah Hegazi, 2024). The Ministry of Agriculture of Zambia classifies farmers into small-scale, medium-scale, and large-scale based on farm size. Small-scale farmers cultivate up to 5 hectares, medium-scale farmers manage 5-20 hectares, and large-scale farmers have over 20 hectares. Among small and medium-scale farming households, 72% cultivate less than 2 hectares, 21% manage between 2 and 4.99 hectares, and 7% cultivate between 5 and 19.99 hectares.

Zambian small-scale farmers employ various farming strategies, ranging from hand hoe cultivation of less than 1 hectare mainly for household food to cultivating 3-4 hectares with a portion allocated to cash cropping. The sector is largely non-mechanized and rain-fed (CGIAR, CCAFS, CIAT, 2019). Key crops include staple foods like maize, sorghum, millet, cassava, and sweet potatoes, as well as cash crops such as tobacco, cotton, sugarcane, coffee, and tea. Horticultural crops like tomatoes, onions, cabbages, and fruits such as bananas, mangoes, and citrus, along with legumes and oilseeds like groundnuts, soybeans, and sunflowers, are also significant.

The agricultural sector is a major contributor to Zambia's greenhouse gas emissions, accounting for about 23% in 2018 (African Development Bank, 2018). The prevalent use of traditional farming practices poses a major challenge in reducing these emissions, as these methods often result in inefficient resource use and higher emissions. Small-scale farmers, who primarily rely on rainfall for their crops, are the most affected by climate change (International Monetary Fund: African Dept., 2023). Over the years, the increasing frequency and severity of droughts and floods have exacerbated the situation (International Monetary Fund: African Dept., 2023).

The low productivity resulting from these climate impacts leads to deforestation, as farmers clear more land to sustain or boost their production and income. In 2021, Zambia's annual deforestation rate was estimated at 300 000 hectares, one of the highest globally. Agricultural activities, after charcoal production, are significant contributors to GHG emissions. Zambia's forest area has consistently decreased from 286,420 km^2 in 2015 to 269,540 km^2 in 2023 (International Monetary Fund: African Dept., 2023). This deforestation trend further elevates GHG emissions, worsening the long-term impact on the agriculture sector through unpredictable weather patterns. The effects on rainfall patterns vary across different regions, further complicating agricultural development (World Bank, 2019).

Additionally, Zambia faces significant post-harvest food losses due to inadequate storage facilities, pests, and poor handling practices, with maize losses reaching up to 30% (Kellan Hays, 2014). Various initiatives, including improved storage technologies and farmer training, are being implemented to address these challenges.

2.2 TRENDS OF LAND USE CHANGE

The trends in land use change in Zambia's agricultural sector, are characterized by expansion and intensification of agricultural activities, deforestation, a shift towards commercial farming, and the impacts of climate change. These changes are influenced by a combination of economic, environmental, and policy factors, all of which play a crucial role in shaping the future of agriculture in Zambia (Phiri, Morgenroth, & Xu, 2019).

Recent trends in Zambia's agricultural sector show a significant increase in agricultural land expansion, driven by growing food and cash crop demands. This often results in converting forests and natural ecosystems into farmland (Phiri, Morgenroth, & Xu, 2019). The FAO reports a steady rise in Zambia's cropland area, from 280,000 km^2 in 2015 to 296,000 km^2 in 2023, indicating a shift from subsistence to extensive agricultural practices. Similarly, arable land has increased from 51,000 km^2 in 2015 to 59,000 km^2 in 2023 (FAOSTAT, 2022). This expansion has led to deforestation, threatening biodiversity and contributing to greenhouse gas emissions. Efforts to mitigate this include sustainable land management and reforestation programmes.

Another notable trend is the intensification of agriculture. There is a growing adoption of more intensive farming techniques, including the use of improved seeds and fertilizers, aimed at increasing productivity on existing agricultural land rather than expanding into new areas. Climate-smart agriculture practices are being promoted to enhance resilience to climate change while maintaining or increasing productivity **Invalid source specified.**.

Additionally, there is a shift from smallholder farming to more large-scale commercial farming. This transition is encouraged by government policies designed to boost agricultural productivity and attract private investment in the sector (Ministry of Agriculture and Cooperatives, Republic of Zambia, 2011). The development of farm blocks and agricultural zones facilitates large-scale farming and agro-industrial activities, reflecting this trend towards commercialization.

Climate change is also significantly influencing land use patterns. Some areas in Zambia are experiencing changes in the suitability for certain crops, leading to shifts in the types of crops being cultivated and the regions where they are grown. The increasing frequency of droughts and erratic rainfall patterns are prompting changes in land use practices, with a growing emphasis on cultivating drought-resistant crops and implementing irrigation systems to ensure sustainable agricultural production.

2.3 NATIONAL AND SECTORAL POLICY LANDSCAPE

To fully exploit agriculture, Zambia has developed well-articulated agricultural policies and strategies which emphasize objectives such as attainment of food security, maximizing farmers' incomes, promoting sustainable agriculture, and enhancing private sector roles in input and output markets.

Zambia's 8th National Development Plan (8NDP 2022-2026) (Ministry of Finance and National Development, Republic of Zambia, 2022) - 2027) is a comprehensive, multi-sectoral strategy designed to achieve several key objectives: enhancing living standards, reducing poverty and inequality, fostering inclusive growth, driving economic transformation, and creating jobs through targeted interventions in agriculture, tourism, mining, and manufacturing. The plan also emphasizes an export-oriented economic transformation to bring Zambia closer to its Vision 2030 goal of becoming a prosperous middle-income country. As part of its macroeconomic reforms, the government aims to overhaul the Farmer Input Support Programme (FISP) by launching a broad agricultural support initiative in the 2022/2023 farming season. This initiative will focus on boosting production and productivity through improved extension services, better access to finance, value addition, and enhanced storage and logistics. The new programme seeks to rectify the inefficiencies and target issues of the current FISP to ensure equitable support for small-scale farmers.

Zambia's Second National Agricultural Policy (2016) (Ministry of Agriculture and Ministry of Fisheries and Livestock, 2016) provides a framework to encourage sustainable agricultural diversification, commercialization, and active private sector involvement, aiming for inclusive agricultural growth. The policy was designed to boost competitiveness, enhance efficiency, and increase both productivity and profitability within the agricultural sector. These initiatives are intended to significantly contribute to food and nutrition security, job creation, higher incomes, and reduced rural poverty. The policy also recognizes high post-harvest losses as a significant challenge. One of its key objectives is to address and reduce these losses through specific measures such as building and rehabilitating silos, constructing cooperative storage facilities, and implementing fumigation processes.

Zambia's National Agriculture Policy (revised NAP 2012-2030) (Ministry of Agriculture and Cooperatives, Republic of Zambia, 2011) provides policy recommendations and action areas to enable agribusiness to produce and commercialise in an environment with clear rules that are predictable and stable, with the government focusing on facilitating, supporting and providing incentives for productive activities. It also provides guidelines for post-harvest loss reduction and management through the *National Food and Nutrition Policy (NFNP)* (Ministry of Health, Republic of Zambia), which includes provisions for the reduction of post-harvest losses in line with the national economic vision 2030, the derived agriculture vision is: "A Competitive and diversified agricultural sector driven by equitable and sustainable agricultural development". The policy acknowledges that "many extension workers have limited exposure and access to new technologies meant to increase production, storage services and facilities meant to reduce post-harvest losses, skills to prevent and control of major diseases and pests, and knowledge of agricultural markets. Even when extension workers have the required knowledge and skills, they are often constrained by inadequate funding". The objectives of NAP 2012–2030 are to:

- Promote sustainable increase in agricultural productivity of major crops with comparative advantage (including strengthening capacity building for small scale farmers on the appropriate crop husbandry practices to minimise the costs, increase production and reduce post-harvest losses.
- Continuously improve agricultural input and product markets (including improving rural storage and strengthening capacity of small-scale farmers to reduce post-harvest losses).
- Increase agricultural exports to preferential markets at regional and international levels.
- Improve access to productive resources and services for small-scale farmers, especially women and young farmers, in outlying areas to enable them to increase production of staple foods, including fruits and vegetables, for own consumption and the surplus for income generation.
- Continuously strengthen public and private sector institutional capabilities to improve agricultural policy implementation, resource mobilisation, agriculture research, technology dissemination, and implementation of regulatory services.

Zambia Comprehensive Agricultural Transformation Support Programme (CATSP): The CATSP is Zambia's Second National Agriculture Investment Plan (NAIP II). The CATSP has been designed in response to national, continental and international aspirations of agri-food systems. The CATSP further provides opportunities for implementing the Food Systems Pathways developed and agreed upon as part of the 2021 UN Food Systems Summit. In particular, aims to accelerate SDG 1 in ending poverty and SDG 13 to take urgent action to combat climate change and its impacts in the Agricultural Sector. Specifically, one of CATSP's expected Outcome Result aims at 'increased agriculture sector's contribution to economic growth, wealth creation and social welfare', aims at reduction in post-harvest losses including promoting storage facilities, equipment, testing facilities, aggregations enterprises, transport facilities etc.

Zambia's Climate-Smart Agriculture Investment Plan (CSAIP 2019) ***Invalid source specified.:*** under its Zambia climate-smart agriculture (CSA) strategy framework, the Government of Zambia (GoZ) is promoting the rollout of CSA practices that will sustainably increase productivity, enhance resilience, and reduce or remove greenhouse gas (GHG) emissions. The CSA investment plan (CSAIP) aims to identify and fill knowledge gaps about CSA's local- and national-level benefits, specifically under climate change, inform policy development, and prioritize investment opportunities.

Among the range of CSA practices, crop diversification and strategies of reducing post-harvest losses seem most promising in achieving welfare and sectoral development goals. Further support development of market infrastructure such as rural storage facilities and enable greater private investment in storage. Private investment may occur where production levels are high and stable and where access to border markets is feasible. In places where these conditions are not met, public investment may be required. In addition, training and collective action on improved post-harvest management bears a high potential to achieve CSA triple-benefits.

Following the food price crisis in 2007/2008, there is a renewed interest in reducing post-harvest losses in Zambia. There are four major reasons to address post-harvest loss: (1) improve food security; (2) improve food safety; (3) reduce unnecessary input use and (4) increase profits for food value actors. Food loss and waste can take place at all stages of the value chain between the farmers field and the consumers fork, which can be divided into five stages (FAO 2011): (1) harvesting due to mechanical damage and/or spillage, (2) post-harvest loss, which includes drying, winnowing, and storage (insect pests, rodents, rotting), (3) processing, (4) distribution and marketing, and (5) consumption. CSAIP also acknowledges the fact that most data on post-harvest loss is spotty and often of poor quality. Nevertheless, climate change projections confirm that CSA has a positive impact on total production, an effect that could be enhanced by reducing post-harvest losses and adopting agroforestry and minimum soil disturbance.

Two key documents in the field of climate change in Zambia are National Policy on Climate Change (NPCC) (2016) (Policy Monitoring and Research Centre of Zambia, 2016) and Nationally Determined Contribution (NDC) of Zambia for the timeframe 2015-2030 (Republic of Zambia, 2021). According to NPCC, climate change has emerged as one of the most pressing issues in Zambia affecting socio economic development. The country is already experiencing climate induced hazards, which include drought and dry spells, seasonal and flash floods and extreme temperatures. Some of these hazards, especially the droughts and floods have increased in frequency and intensity over the past few decades and have adversely impacted on the food and water security, water quality, energy and sustainable livelihoods. Agriculture sector, which employs 67% of the labour force, remains the main source of income and employment particularly for both rural women and men. It is being highly dependent on rainfall, and therefore very sensitive to climate change. The resultant adverse impacts on crops lead to reduction of agricultural productivity thereby contributing to food insecurity. The increase in temperatures has resulted in increased difficulties in the control and management of pests and diseases. Droughts and flooding have also resulted in crop failure, reduced livestock production and the consequent food insecurity. Climate variability has kept a proportion of the population dependent on subsistence agriculture, below the national poverty line.

The overall objective of the National Policy on Climate Change (2016) is to provide a framework for coordinating climate change programmes to ensure climate resilient and low carbon development pathways for sustainable development towards the attainment of Zambia's Vision 2030.

The adaptation and disaster risk reduction efforts will include measures to: Strengthen the mechanism for identifying risks and hazards in order to facilitate planning and early warning; Strengthen surveillance and control of climate change related pests and diseases; Strengthen the resilience of infrastructure, ecosystems and promote innovation, knowledge and education; Promote the adoption of appropriate Climate Smart Agricultural (CSA) technologies for different agro-ecological zones; Promote the communities' ability to develop physical and social infrastructure that are resilient to the adverse effects of climate change.

In conjunction to increase the resilience of livelihoods to disasters, the policy also introduces actions that will help making agriculture, forestry, and fisheries more productive and sustainable by promoting investments in climate resilient and low carbon development pathways to generate co-benefits and provide incentives for addressing climate change more effectively. To this end, efforts will be focused on:

- Promoting sustainable land use planning to protect key ecosystems and related services such as carbon sinks.
- Promoting landscape-based livelihood diversification.
- Promoting the development and implementation of Nationally - Appropriate Mitigation Action (NAMAs) in the sectors.

- Ensuring that investments adhere to sustainable development principles and are in line with low-carbon development principles.
- And reducing forest degradation and loss of forest ecosystems.

Zambia's NDC (Republic of Zambia, 2021) recognizes agriculture as one of the key sectors that are responsible for emissions of GHGs and presents a conditional pledge of reducing GHG emissions by 25% (20,000 Gg CO_2 eq.) by 2030 against the base year of 2010 under the Business As Usual (BAU) scenario with limited international support, or by 47% (38,000 Gg CO_2 eq.) with substantial international support. The NDC of 2016 recognizes that agriculture waste, including food losses reduction could contribute to its emissions reduction target of 38,000 Gg CO_2 eq by 2030. As a minimal contributor to global GHG emissions, Zambia has prioritised adaptation efforts in response to climate change particularly in the agriculture sector.

Zambia's revised NDC consists of both mitigation and adaptation components. The mitigation actions are focused on sustainable agriculture among other areas. Adaptation actions in this NDC are focused on strategic productive, strategic infrastructure, enhanced capacity building, research, technology transfer and finance for adaptation. In 2021, Zambia enhanced its NDC by broadening the scope of sectors under mitigation and by elaborating the adaptation component of the NDC by developing indicators that will enable the country to track progress on building resilience in both the human and physical systems and on adaptation actions. Specifically in relation to agriculture, Zambia's role in global food security in the context of climate change is to adapt to a changing climate, manage and use these resources sustainably, to secure food supplies while reducing greenhouse gas emissions.

2.4 LEGAL AND REGULATORY LANDSCAPE

Zambia has several legal and regulatory frameworks aimed at governing agricultural production, and related environmental and climate aspects of it. These regulations are designed to enhance productivity, ensure food security, and promote sustainable agricultural practices.

The Environmental Management Act No 12 of 2011 (Republic of Zambia, 2011) ensures environmental protection and sustainable use of natural resources in all sectors, including agriculture. Key provisions cover environmental impact assessments, guidelines for sustainable farming practices, and measures to mitigate the environmental impact of agricultural activities.

The Agricultural Credit Act No 35 of 2010 (Republic of Zambia, 2010) facilitates access to credit for farmers to invest in agricultural inputs and infrastructure. Key provisions include regulations on the provision of agricultural loans, guarantees, and subsidies.

The Food and Nutrition Act No 3 of 2020 (Republic of Zambia, 2020)includes strategies for improving food production, nutrition education, etc. The Act sets up a Coordinating Committee responsible for coordination of the multi-sectoral response to national food and nutrition programme and provides for the membership to represent permanent secretaries of health, agriculture, community development, fisheries and livestock,

2.5 GCF COUNTRY PROGRAMME DETAILS

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

The Green Climate Fund (GCF) is currently implementing nine projects in Zambia (Table 2-1), with a total financing amount of 138.7 million USD. Additionally, the GCF has approved four country-level readiness activities with a combined budget of 3.1 million USD, out of which 2.6 million USD has already been disbursed.

Table 2-1 – GCF Portfolio in Zambia

Project code	Focus	Geographical scope	Project title
FP222	Cross-cutting	Africa (Cameroon, Lesotho, Malawi, Nigeria, Zambia, Democratic Republic of the Congo, Madagascar, Niger)	Renewable Energy Performance Platform (REPP 2)
FP212	Cross-cutting	Latin America and the Caribbean, Africa, Asia-Pacific (9 countries)	Green Fund: Investing in Inclusive Agriculture and Protecting Forests
FP211	Cross-cutting	Africa (16 countries)	Hardest-to-Reach
FP210	Cross-cutting	Africa (Cote d'Ivoire, Kenya, Rwanda, Zambia, Democratic Republic of the Congo, Nigeria, Uganda)	KawiSafi II
FP205	Adaptation	Africa (19 countries)	Infrastructure Climate Resilient Fund (ICRF)
FP148	Mitigation	Africa (9 countries)	Participation in Energy Access Relief Facility ("EARF")
FP099	Mitigation	Latin America and the Caribbean, Africa, Asia-Pacific (19 countries)	Climate Investor One
FP080	Mitigation	Zambia	Zambia Renewable Energy Financing Framework
FP072	Adaptation	Zambia	Strengthening climate resilience of agricultural livelihoods in Agro-Ecological Regions I and II in Zambia

Among the projects, the most significant for the agricultural sector is FP072 Strengthening climate resilience of agricultural livelihoods in Agro-Ecological Regions I and II in Zambia (Green Climate Fund, 2018). This project spans seven years (2018-2025) and targets increasing the climate resilience of smallholder farmers in designated regions. Zambia, a landlocked nation where about 70% of the workforce relies on rain-fed agriculture, is particularly susceptible to climate-induced precipitation changes. While floods often cause immediate disasters, the increasing frequency of droughts poses a long-term threat to the country's agricultural livelihoods. The project focuses on smallholder farmers across five provinces: Eastern, Lusaka, Muchinga, Southern, and Western. It adopts a value-chain approach, offering several benefits such as enhanced access to climate information services, support for climate-resilient agricultural inputs and practices, sustainable water management, and alternative livelihood options.

2.5.2 Other relevant projects (on food losses)

Besides GCF, some of the major donors working on the projects related to post-harvest food losses in Zambia include Food and Agriculture Organisation of the United Nation (FAO), the World Food Programme (WFP), USAID, and others. Some of the major ongoing projects and initiatives include:

Post-Harvest Loss Reduction Initiative: FAO continues to work with the Zambian government on various initiatives aimed at reducing post-harvest losses. These efforts include ongoing training programmes for farmers and the distribution of improved storage technologies.

Zero Post-Harvest Losses Project (UN World Food Programme, 2024)**:** With the support of the Innovation Accelerator, WFP is training smallholder farmers on how to reduce cereal and legume losses and use improved post-harvest handling methods, combined with simple but effective hermetic storage equipment (storage bags, metal silos). The equipment—which is subsidized—is both air and watertight, helping to guard against insects, rodents, mould, and moisture. The project is part of WFP's broader efforts to enhance food security in Zambia.

USAID/ Prosper Africa/ BECHTEL Zambia Partnership (USAID, 2022): announced in 2022, The partnership between Africa Global Schaffer, Bechtel, and Export Trading Group will initially work in Zambia. While 80% of smallholder farmers in Zambia produce maize, maize contributes up to 30% of the country's post-harvest losses. When surplus maize is wasted and damaged maize is sold for less than its value, market dynamics, stability, and job growth are all impacted. This partnership will help to solve these challenges by building green, Smart Integrated District Aggregation Centres in areas where improving production will have huge impacts. The centres will connect sellers with buyers at key points along East African trade routes to improve the availability of high-quality maize and other agriculture commodities as well as protect farmer incomes that are suffering from the increase in prices related to agricultural inputs. They will also provide logistics support and equipment to protect post-harvest crops as well as transaction support to promote volume sales to boost food security.

The first phase of the partnership will prioritize the construction, start-up, and operationalization of seven centres in high-production areas in Zambia by the May harvest season. Then, the programme will scale up to 23 centres to provide approximately 100,000 metric tonnes of maize and other crops and potentially avoid more than 800 metric tonnes of carbon – equivalent to around 80,000 gallons of consumed diesel. Moreover, one-third of the centres will be run by women smallholder farmers. Eliminating Zambia's post-harvest maize loss will also provide over 1.5 million people with their necessary calorie requirements, thus significantly reducing hunger and malnutrition.

3 Climate analysis - Adaptation

3.1 COUNTRY CLIMATE CHANGE BASELINE

Under the Köppen Geiger climate classification system, Zambia is largely characterised by a humid sub-tropical climate (Government of the Republic of Zambia, 2020). However, there are also regions of semi-arid steppe grasslands in the southwest of the country (USAID, 2016), along the Zambezi valley (Government of the Republic of Zambia, 2020). The climate also varies based on elevation and latitude, including the influence of Zambia's elevated Sandveld plateau area (AfDB and the University of Cape Town, 2018).

Rain predominantly occurs during the summer months (December through March), and the period from May through September is the dry season (AfDB and the University of Cape Town, 2018). Zambia experiences a great deal of rainfall variability, due to the influence of the Inter Tropical Convergence Zone (ITCZ) as well as the El Niño Southern Oscillation (ENSO) effect (USAID, 2016). Rainfall tends to be higher in the north (as much as 1 300 mm annually) and decreases towards the south (as little as 600 mm annually, on average) (Government of the Republic of Zambia, 2020).

Historical trends (based on observations between 1960 and 2006) suggest that climate change has already influenced an increase in average temperatures. The main observed trends over this period include (USAID, 2016):

- An **average temperature increase** of approximately 1.3˚C, especially during the winter (June–Aug)
- An **increase in the average number of hot days and nights**, as well as a decrease in the average number of cold days and nights.
- A **decrease in average rainfall throughout the year**, but with the decrease more pronounced during the wet season.
- An increase in the frequency and intensity of extreme weather events such as floods and droughts.

In recent decades the rate of increase in average temperatures has slowed marginally, but the overall trend is a rising one, as captured in, Figure 3-2 and Figure 3-3.

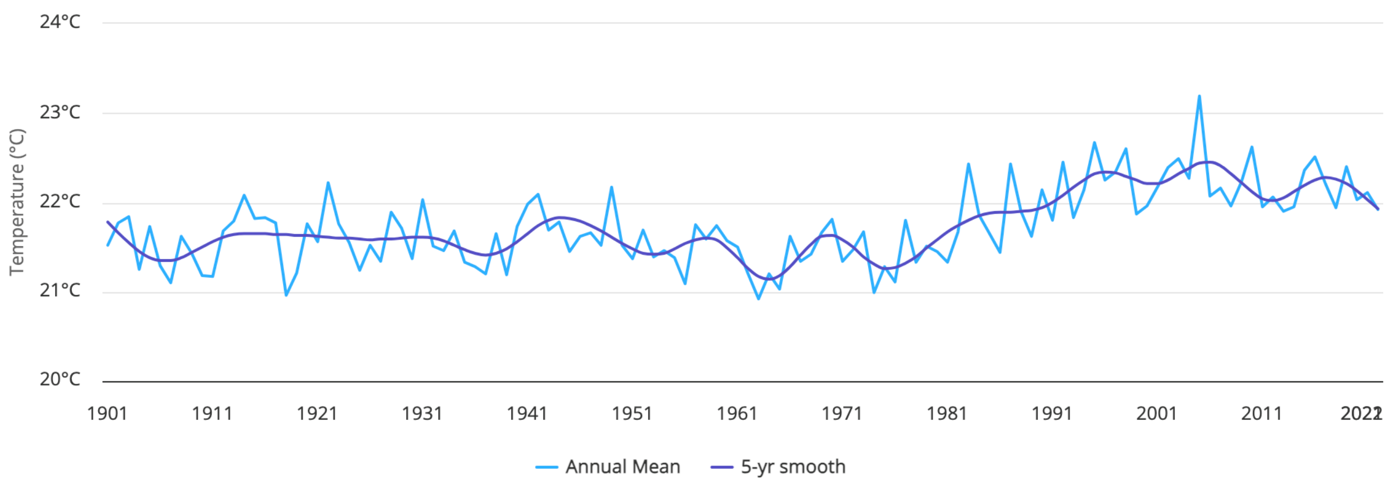


Figure 3-1- Observed annual average mean surface air temperature of Zambia, 1901 - 2022 (World Bank, Climate Change Knowledge Portal)

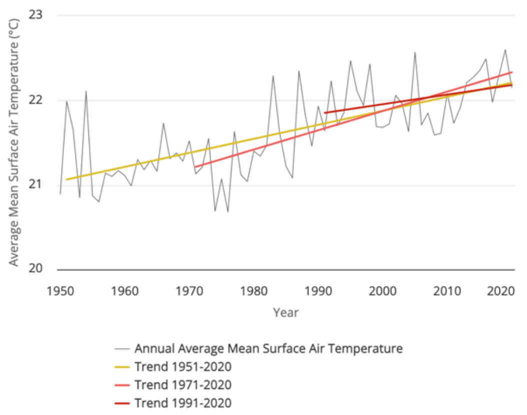


Figure 3-2 - Average mean surface air temperature annual trends with significance of trend per decade, 1951 - 2020, Zambia (World Bank, Climate Change Knowledge Portal)

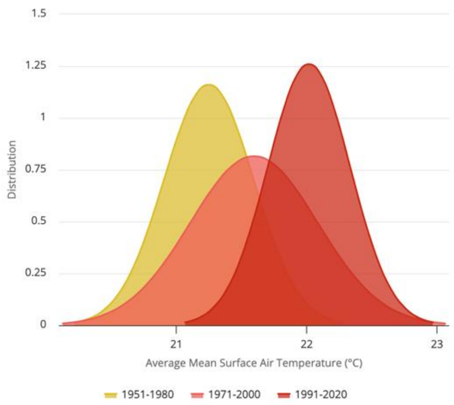


Figure 3-3 - Change in distribution of average mean surface air temperature, 1951-2020, Zambia (World Bank, Climate Change Knowledge Portal)

Historic long-term trends for total annual rainfall in Zambia since the 1990s are positive, i.e., indicate an increase, over all regions except for the northern highlands. However, trends in the frequency of extreme rainfall events are not discernible (AfDB and the University of Cape Town, 2018). Figure 3-4 and Figure 3-5 below demonstrate the historic natural variability in rainfall, and the slightly increasing signal with climate change in the most recent decades.

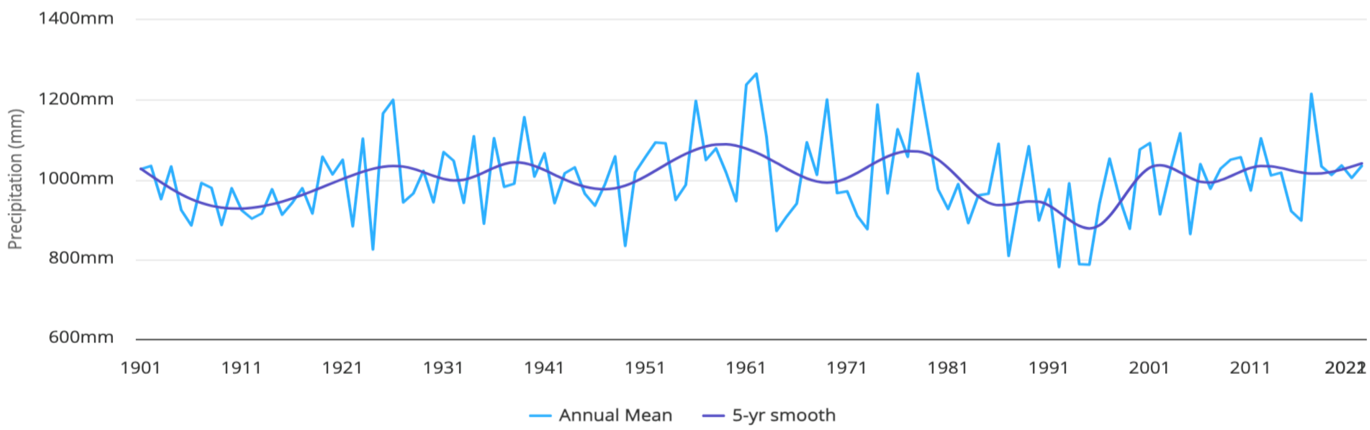


Figure 3-4 – Observed Annual Precipitation of Zambia (1901 - 2022) (The World Bank, Climate Change Knowledge Portal)

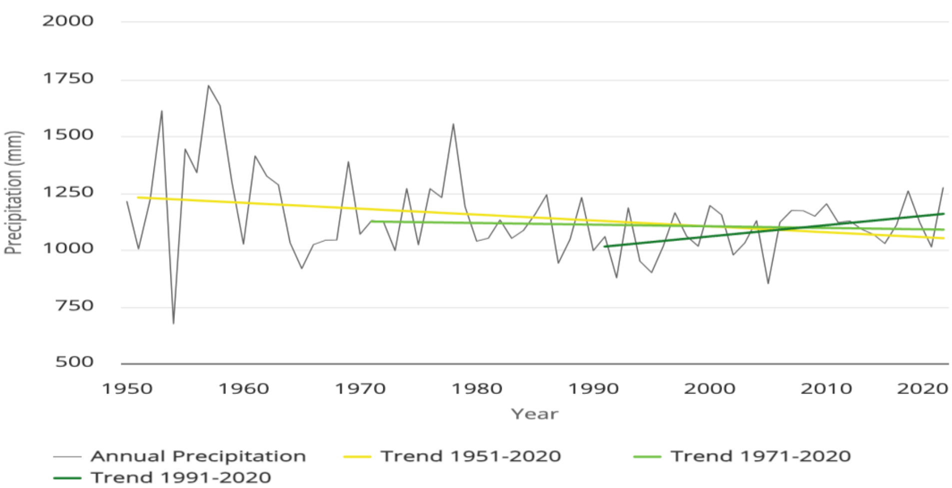


Figure 3-5 - Precipitation annual trends with significance of trend per decade in Zambia (1951- 2020) (The World Bank, Climate Change Knowledge Portal)

Zambia has historically not been highly prone to climate-related extreme weather events and has had a relatively low risk of major natural disasters. The most recent Germanwatch climate risk index for cumulative disaster-related losses between 2000-2019 ranks Zambia as 123rd out of 180 countries (Eckstein, Künzel, & Schäfer, 2022). According to the EU's INFORM climate risk index, even though Zambia's baseline vulnerability to climate-related hazards is above average (5.8 out of 10), and its lack of coping capacity is also greater than average (6 out of 10), its low exposure to climate-related hazards (2.1 out of 10) renders its overall climate risk relatively below average (4.2 out of 10) (European Commission, n.d.).

Since 2000, Zambia has experienced more frequent and intense droughts, dry spells, flooding events, and flash floods. These have had negative impacts on most major economic sectors and have caused substantial loss of livelihoods and economic activity (Government of the Republic of Zambia, 2020). Floods, in particular, have taken a toll. For instance, flooding during the 2009-2010 rainy season, due to heavy rainfall, resulted in the destruction of crops, an increase in human and animal diseases, significant damage to roads, plus damage to health and educational and housing infrastructure (Government of the Republic of Zambia, 2020). Different regions of Zambia have also grappled with divergent challenges in terms of extreme weather, as Zambia experienced in the 2011-2012 rainy season when there were floods in the northern half but dry spells in the southern half of the country, all of which contributed to greater food insecurity (Government of the Republic of Zambia, 2020).

3.2 AGRICULTURE SECTOR CLIMATE CHANGE BASELINE

Even though the agriculture sector (including forestry and fisheries) only contributes an estimated 3.1% of Zambia's total national GDP, the sector accounts for approximately 57% of the country's total employment (The World Bank, n.d.). The government of Zambia considers agriculture the backbone of the rural population, the vast majority of whom depend on the sector as their main source of income and livelihood (Government of the Republic of Zambia, 2020). The sector is highly vulnerable to climate change, given that most cultivators are smallholder, poor, and dependent on rain-fed subsistence agriculture (Government of the Republic of Zambia, 2020). Such groups are typically under-resourced and under-capacitated to cope with shocks and stressors.

Maize is Zambia's key staple crop, and 60% of it is grown by subsistence farmers (African Climate Foundation, IFPRI, and CGIAR, 2023). A large portion of Zambia's agricultural export revenues are also linked to maize (CGIAR, CCAFS, CIAT, 2019). Maize accounts for nearly half (49%) of agricultural land use (total harvested area) in Zambia (CGIAR, CCAFS, CIAT, 2019). Along with wheat, maize is responsible for meeting 60% of the population's caloric needs (African Climate Foundation, IFPRI, and CGIAR, 2023).

Maize needs timely rainfall and stable temperature for good yields (African Climate Foundation, IFPRI, and CGIAR, 2023). The IPCC's synthesis of global literature observed climate change impacts on major crops indicates that maize as well as rice yields in sub-Saharan Africa, have displayed negative trends under a steadily warming climate, as captured in Figure 3-6.

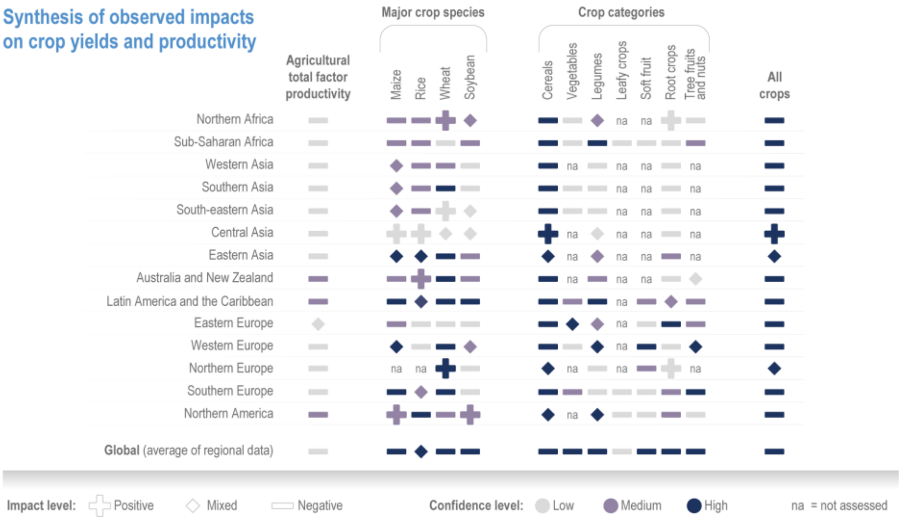


Figure 3-6 - Synthesis of literature on observed impacts of climate change on productivity by crop type and region (IPCC AR6, WG1, Chapter 5, 2022)

In Zambia, recent drought conditions – coupled with an El Niño Southern Oscillation phase – have led to sharply falling maize yields in 2023 and a declaration of a disaster (Glauber & Anderson, 2024).

Table 3-1 - Maize production and yields

Market Year	Area (1000 Ha)	Production (1000 Tons)	Yield (T/Ha)
2013/2014	998	2,533	2.5
2014/2015	1,205	3,351	2.8
2015/2016	964	2,618	2.7
2016/2017	1,158	2,873	2.5
2017/2018	1,434	3,607	2.5
2018/2019	1,086	2,395	2.2
2019/2020	842	2,004	2.4
2020/2021	1,334	3,387	2.5
2021/2022	1,410	3,620	2.6
2022/2023	1,368	2,654	1.9
2023/2024	1,418	3,263	2.3
5-year Average 2018/19 - 2022/23	**1,208**	**2,812**	**2.3**
Percent Change From 5 Year Average (%)	**17**	**16**	**-1**

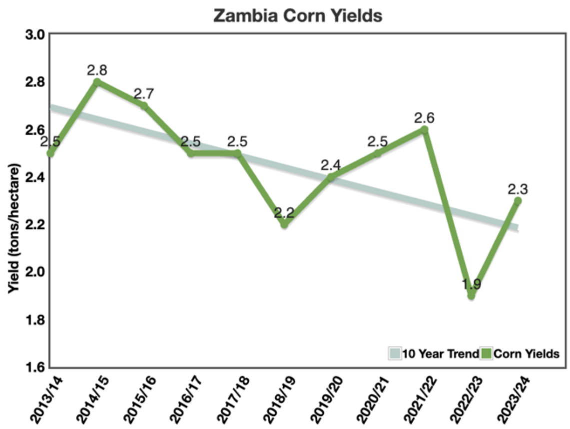


Figure 3-7 - Zambia maize yields, 2013-2024 (USDA FAS IPAD)

However, even before the ENSO event, maize yields over a decadal period displayed a falling trend in Zambia (while total production has risen, as can be seen in Table 3-1, the tonnes per hectare have been falling), as indicated in Figure 3-7.

Legumes such as soybeans are also important crops in Zambia, accounting for 14% of agricultural land use (total harvest area) (CGIAR, CCAFS, CIAT, 2019). Soybeans are not staple crops for subsistence needs in Zambia but are an important cash crop; it is predominantly produced by commercial farms, although smallholder production of soybeans rose in recent decades after logistical support to farmers was offered by parastatals (USAID , 2009). Soybeans have been attractive because they provide good double-cropping opportunities with wheat and rotation with rainfed maize (USAID , 2009). Soybean production is climate-sensitive, and research in Zambia suggests that unpredictable weather patterns increase the risks of low yields and crop failure (Griffin Services Ltd. , 2023).

Similar to the trends with maize, even soybean production has been rising over the last decade in Zambia (as can be seen in Table 3-2), while the yields in terms of tonnes per hectare have been falling, as indicated in (United States Department of Agriculture (USDA), n.d.)

Table 3-2 - Soybean production and yields in Zambia, 2013-2024 (USDA FAS IPAD)

Market Year	Area (1000 Ha)	Production (1000 Tons)	Yield (T/Ha)
2013/2014	125	261	2.1
2014/2015	114	214	1.9
2015/2016	112	226	2.0
2016/2017	138	268	1.9
2017/2018	225	351	1.6
2018/2019	192	303	1.6
2019/2020	196	281	1.4
2020/2021	164	297	1.8
2021/2022	304	411	1.4
2022/2023	375	475	1.3
2023/2024	375	475	1.3
5-year Average 2018/19 - 2022/23	**246**	**353**	**1.5**

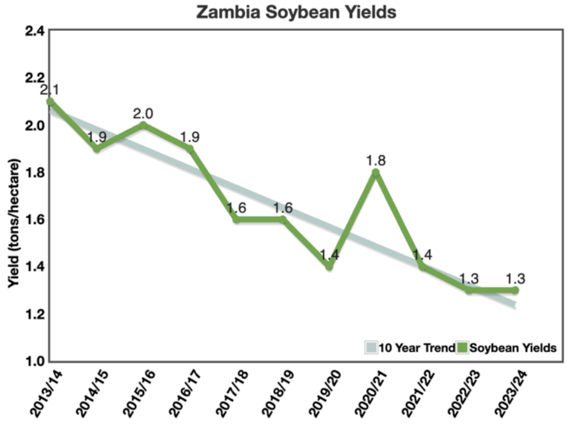


Figure 3-8 - Zambia Soybean yields, 2013-2024 (USDA FAS IPAD)

3.3 COUNTRY CLIMATE CHANGE FUTURE

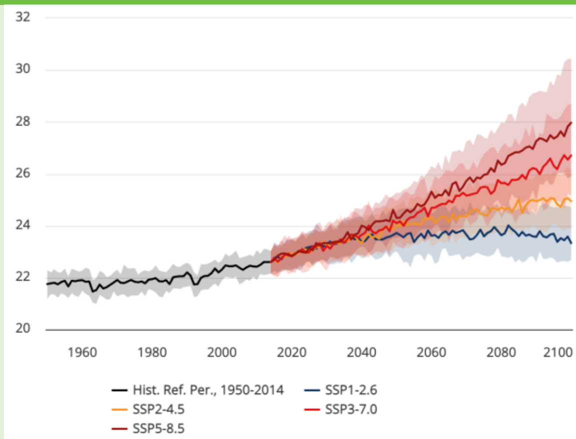
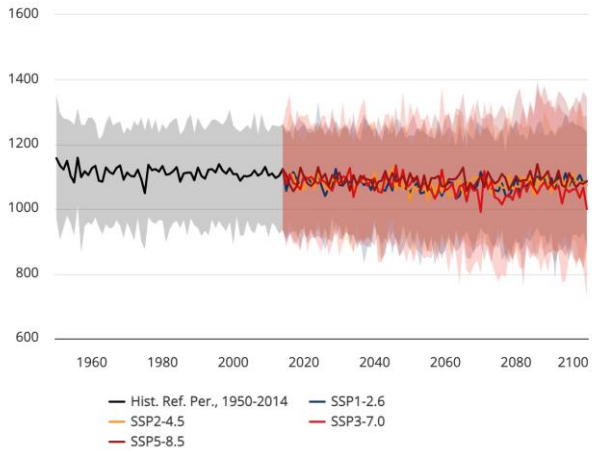
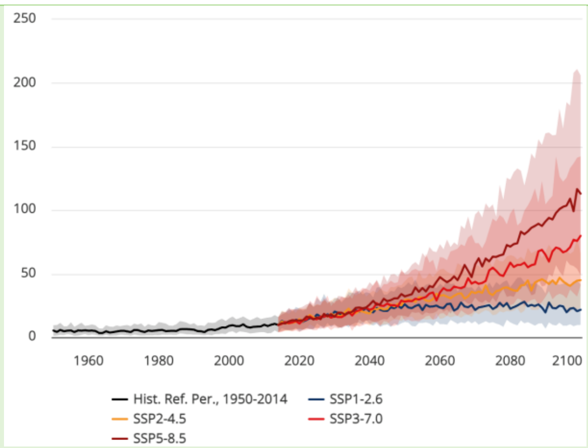
For the analysis of future climate risk to the two crops of interest, Maize (corn) and Soybeans (soy), our assessment looks at the 2040 time horizon (a timescale relevant to RE-GAIN's programmatic interventions). To identify future climate conditions that would (i) signal the major climate-driven threats 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, project analytics took 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).

A quantitative component of the climate risk assessment (see Excel Annex, workbook "Zambia"), was undertaken and integrated the findings from that assessment with qualitative excerpts from relevant sources and literature, coupled with inputs from the 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 Zambia, focused on the 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 Zambia 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 3-9 - Projected average mean surface temperature under multiple future scenarios (World Bank Climate Change Knowledge Portal: Zambia)*
Mean Precipitation	Across all future climate scenarios, mean precipitation displays minor variability in climate projections, relative to the historic baseline (reference period 1950-2014). There appears to be a marginal downward trend for the future but without a substantial departure from the baseline. 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 slight decreasing signal).	 *Figure 3-10- Projected mean precipitation under multiple future scenarios (World Bank Climate Change Knowledge Portal: Zambia)*
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 an increasing trend (except SSP1-2.6). The rise is more pronounced towards end-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 such days in the year, projections of potentially ~18 (SSP 2-4.5) or even ~25 (SSP 5-8.5) such days in 2040 is a remarkable 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 3-11 - Projected change in number of hot days with temperature over 35°C, under multiple future scenarios (World Bank Climate Change Knowledge Portal: Zambia)*

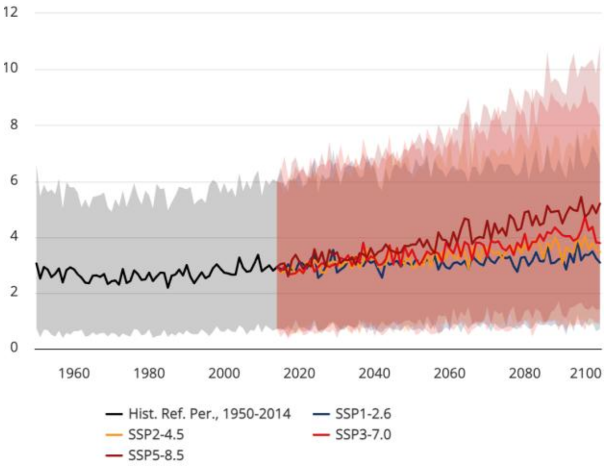
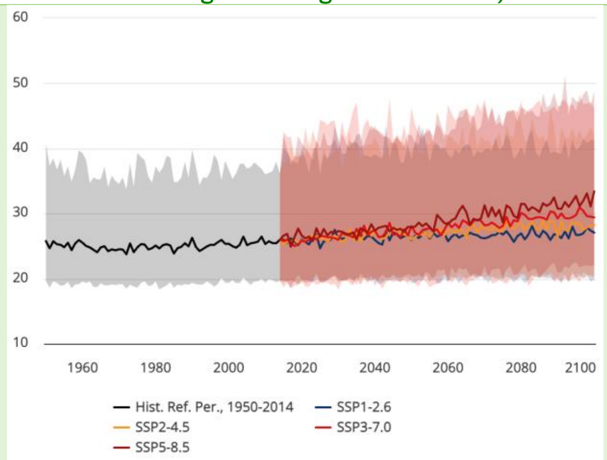
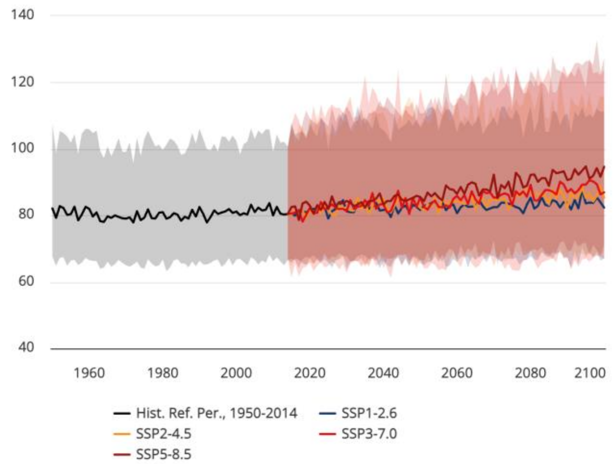
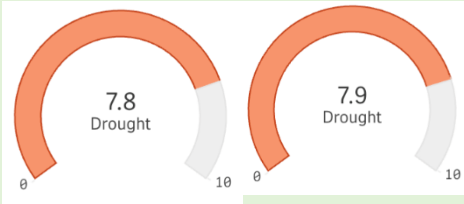
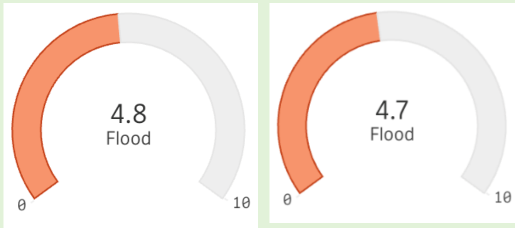
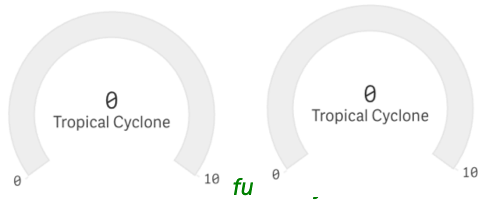
Variable Name	In-Country Context Description	Additional information
Number of days with precipitation >20 mm	Across all future climate scenarios, the average number of days with rainfall greater than 20mm displays a rising trend (except SSP1-2.6). The rise is more pronounced towards the end of the century, but even in 2040, the number of such days increases unambiguously from the historic baseline (reference period 1950-2014). Given that in the past there were on average 2.6 such days in the year, projections of potentially ~3.3 (SSP 2-4.5 and (SSP 5-8.5) such days in 2040 is a notable percentage change. Thus, in our assessment, based on the percentage change we found that the estimated change in the number of days with precipitation >20 mm is **very high**.	 *Figure 3-12 - Projected change in number of days with rainfall >20 mm, under multiple future scenarios (World Bank Climate Change Knowledge Portal: Zambia)*
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 fair degree of variability in climate projections, relative to the historic baseline (reference period 1950-2014). Towards the end of the century, there is an increasing signal (except in SSP1-2.6), however, even for the 2040 period, the increase is substantial in percentage terms. 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 3-13 - Projected change in average largest single-day precipitation, under multiple future scenarios (World Bank Climate Change Knowledge Portal: Zambia)*
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 far 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), in percentage terms we found that the estimated change in rainfall was **moderate** (with a slightly increasing signal).	 *Figure 3-14 - Projected change in average largest five-day precipitation, under multiple future scenarios (World Bank Climate Change Knowledge Portal: Zambia)*

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)	Zambia's future water scarcity risk in the face of climate change is regarded as **moderate (medium)**. This implies that "there is up to a 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 6.1 (out of 10), under both SSP2-4.5 (to 7.8 out of 10) and SSP5-8.5 (7.9 out of 10), both of which are high (European Commission, n.d.).	 *Figure 3-15 – Zambia'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	Zambia's future extreme heat risk due to climate change is regarded as **moderate (medium)**. 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)	Zambia'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.). The risk of floods in Zambia due to climate change is not as high, according to the INFORM Climate Change Risk Index. Per index, Zambia's baseline risk of flooding (on a 0-10 scale) is 4.8 as of 2022. Under the SSP2-4.5 scenario for mid-century (2050), this remains 4.8, and under the SSP5-8.5 scenario, this diminishes ever so slightly to 4.7 for the same period (European Commission, n.d.).	 *Figure 3-16- Zambia'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	Zambia's future wildfire risk due to climate change (and other factors) is regarded as **high**. 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.]	N/A
Landslides	Zambia's future landslide (or landslip) risk due to climate change (and other factors) is regarded as **low.** This indicates that the country "has rainfall patterns, terrain slope, geology, soil, land cover and (potentially) earthquakes that make localized landslides an uncommon hazard phenomenon." (GFDRR, n.d.). [Note: the INFORM climate risk index does not provide data for landslides.]	N/A

Cyclones	Zambia's future tropical cyclone (or hurricane) risk due to climate change (and other factors) is regarded as **low.** This denotes that "there is a 1% chance of potentially damaging wind speeds…in the next 10 years." (GFDRR, n.d.) According to the INFORM Climate Change Risk Index, Zambia'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.)	 *F fu 50 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

Analysis of crop sensitivity to climate shocks in Zambia indicates that maize will be among the most negatively affected crops, with significant yield reductions, due to anticipated future climate change (Mulenga, Ngoma, & Solomon , 2015). Lower projected maize yields due to climate change have been identified as Zambia's key risk to agriculture (African Climate Foundation, IFPRI, and CGIAR, 2023).

Several studies specific to Zambia suggest varying levels of maize yield decreases linked to climate change. Across all of these, there is consensus that maize yields will fall, albeit with variation across regions and under different future climate change scenarios, and even with variation between different maize varieties. One study, for instance, found that mean maize yield change is projected to decrease in the Central Province, with the decrease getting steeper over time as climate change impacts worsen (Chilambwe, Crespo, & Chungu, 2022). But the same study also found that projected mean yield changes in the Eastern Province remain largely within the historical range of variability, indicating that maize yields in that province may be less sensitive to climate change (Chilambwe, Crespo, & Chungu, 2022).

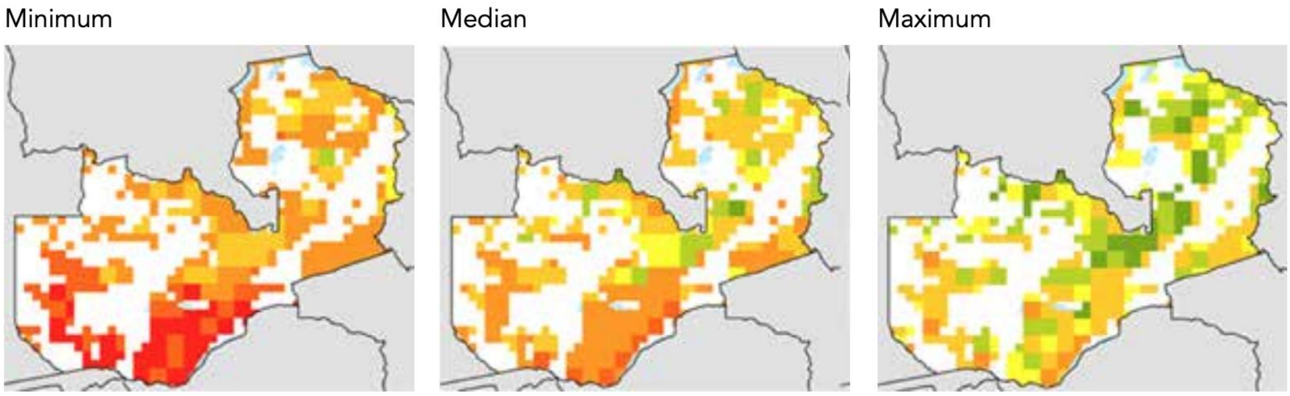
In another study, researchers posit that in the case of long-maturing varieties, all provinces are predicted to undergo significant decreases in the total suitable area for maize cropping (ranging from ~20% in Northwestern province, up to ~77-82% in Copperbelt and Muchinga provinces) (IFAD and the University of Cape Town, 2020). In the case of short-maturing varieties, the study suggests that climate change is likely to result in a decrease in suitability from 'very good' and 'excellent' areas in the baseline, to 'moderate' and 'good' areas in the future scenario (IFAD and the University of Cape Town, 2020).

A third study notes that maize yields under climate change (in comparison to a scenario without climate change) could fall by as much as 8.7% by 2050 (CGIAR, CCAFS, CIAT, 2019). Another paper offers estimates in Table 3-5, below.

Table 3-5 - Yield impact of climate change on maize in 2050 under SSP5-8.5, relative to 2005 climate (African Climate Foundation, 2023)

Without CO_2 fertilization Predicted yield change (%)				With CO_2 fertilization Predicted yield change (%)			
Crop	Minimum	Median	Maximum	Crop	Minimum	Median	Maximum
Maize	-21.76	-9.36	-4.79	Maize	-22.04	-9.84	-5.37

The largest yield declines are likely in the southwest of the country, per modelling studies. See, for instance, Figure 3-18.



Percent yield change, rainfed maize, 2005–2050, RCP8.5, with CO_2 fertilization, across 5 General Circulation Models (GCMs) in Inter-Sectoral Impact Model Intercomparison Project (ISIMIP), CMIP6 (sixth phase of the Coupled Model Intercomparison Project)

Figure 3-18 - Visualization of projected yield changes for maize in Zambia (African Climate Foundation, 2023)

In terms of regional variation in suitability for maize cultivation, under climate change, one study suggests that the greatest change will be in the Southern Province (IFAD and the University of Cape Town, 2020), as reflected in Figure 3-19.

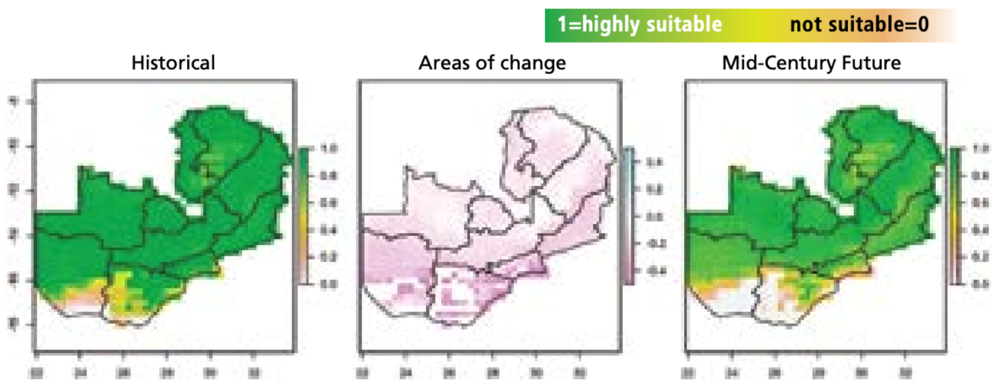


Figure 3-19 - Projected effects of climate change on distribution of suitability for maize in Zambia (IFAD and UCT, 2020)

Overall, the Southern Province, Western Province, and Lusaka are all areas of concern for declines in production (IFAD and the University of Cape Town, 2020).

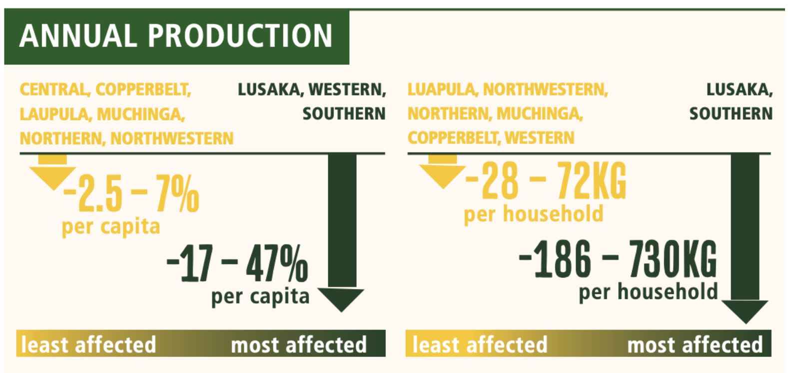


Figure 3-20 - Climate change effects on annual maize production in Zambia - regional variations (IFAD and UCT, 2020)

Note to readers: Published literature is scarce on the climate impacts on post-harvest stages of the maize value chain (in Zambia and globally).

3.4.2 Soybeans

Soybeans are somewhat sensitive to temperature and moisture, as well as pests that are themselves responsive (in terms of breeding cycles and range) to temperature and humidity. Thus, climate change is expected to affect soybean cultivation. Some studies suggest a slight decrease in yields under future climate change scenarios. Estimates from one such study are highlighted in Table 3-6, below.

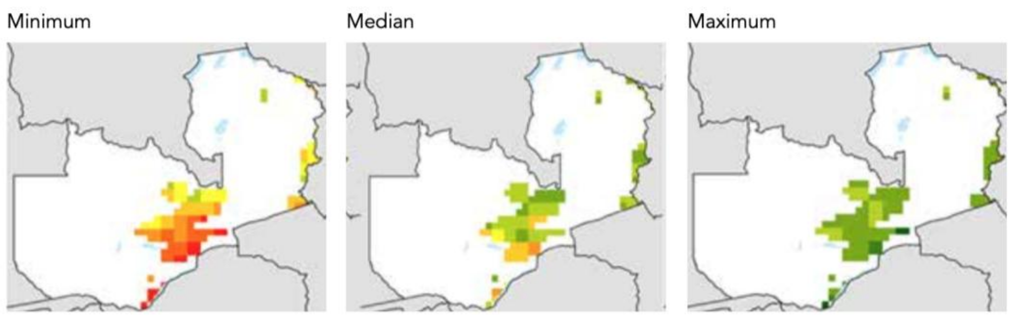
Table 3-6 - Yield impact of climate change on soybeans in 2050 under SSP5-8.5, relative to 2005 climate (African Climate Foundation, 2023)

Without CO_2 fertilization Predicted yield change (%)				With CO_2 fertilization Predicted yield change (%)			
Crop	Minimum	Median	Maximum	Crop	Minimum	Median	Maximum
Soybean	-25.47	-13.03	-6.77	Soybean	-7.29	7.24	13.70

Another study notes that soybean yields under climate change (in comparison to a scenario without climate change) could fall by about 3% by 2050 (CGIAR, CCAFS, CIAT, 2019).

However, other studies have found that soybean yields may even increase in some parts of Zambia, under climate change. For instance, one group of researchers project that mean soybean yield changes in the Central Province consist of a combination of reductions and improvements, while soybean yields in the Eastern Province are projected to increase shortly, with the possibility of even larger increases in the far future (Chilambwe, Crespo, & Chungu, 2022). As such, relative to maize and some other crops in Zambia, soybeans are less sensitive to climate change (Chilambwe, Crespo, & Chungu, 2022).

In terms of regional impacts, studies suggest that soybean cultivation and yields in the Lusaka area will be most affected (African Climate Foundation, IFPRI, and CGIAR, 2023), as depicted in Figure 3-21 below.



Percent yield change, rainfed soybeans, 2005–2050, RCP8.5, with CO_2 fertilization, across 5 ISIMIP GCMs, CMIP6

Figure 3-21 - Visualization of projected yield changes for soybeans in Zambia (African Climate Foundation, 2023)

Substantial research exists in Zambia on climate change impacts on bean production, more broadly (a generic category of legumes, inclusive of but not limited to soybeans). One such study suggests that in terms of regional variation in suitability for bean cultivation, under climate change, Zambia will experience a reduction in total area suitable for bean production, as well as a reduction in the average suitability of cropping areas (IFAD and the University of Cape Town, 2020). According to the study, most provinces across southern, central and northern Zambia are likely to undergo a transition from 'good'/'very good' suitability towards 'marginal'/'good'. As such, all provinces will undergo a decrease in productivity, ranging from -20% (Northwestern) up to -63% (Western) (IFAD and the University of Cape Town, 2020), as displayed in Figure 3-22.

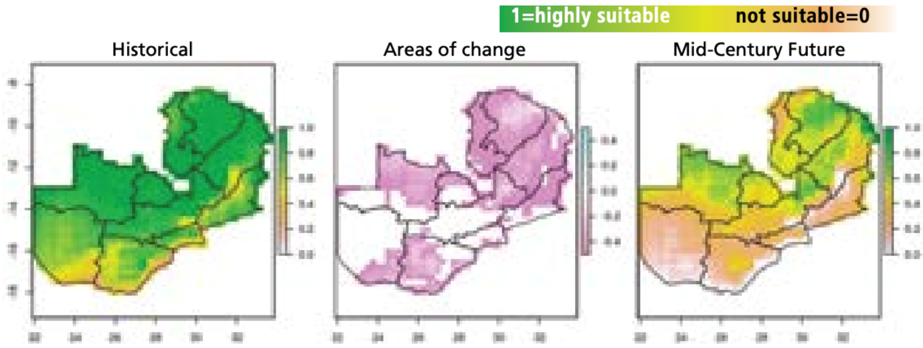


Figure 3-22 - Projected effects of climate change on distribution of suitability for beans in Zambia (IFAD and UCT, 2020)

Note to readers: Published literature is scarce on the climate impacts on post-harvest stages of the soybeans value chain (in Zambia and globally).

3.5 RISK ASSESSMENT FOR POST-HARVEST VALUE CHAIN STAGES

3.5.1 Maize

Our analysis of climate change risks to the Maize value chain in Zambia indicates that the most significant **hazards** are heavy or intense precipitation (extreme volumes of rainfall in a single day period, and the number of days with rainfall over 20 mm), and higher temperatures (most severely the number of days above 35°C, but also the increase in mean annual temperature), flooding (pluvial and fluvial), and wildfires. To a slightly lesser degree, drought and heatwaves also pose a threat.

Zambian 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 **high temperatures and extreme heat, rainfall variability, heavy or intense rainfall (excessive and erratic), drought, and flooding (especially in low-lying areas). They also expressed concerns about the threats of pests and wildfires.**

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

Table 3-7 - Top three climate change hazards identified for Zambia'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
Lusaka	Rainfall variability (erratic and linked to flooding in low-lying areas) Drought	Rainfall variability (erratic and linked to flooding in low-lying areas) Drought	Rainfall variability (erratic and linked to flooding in low-lying areas) Drought

	Rising temperatures (extreme heat)	Rising temperatures (extreme heat)	Rising temperatures (extreme heat)
Chipata	Drought Rainfall variability (erratic and linked to flooding in low-lying areas) Rising temperatures (extreme heat)	Drought Rainfall variability (erratic and linked to flooding in low-lying areas) Rising temperatures (extreme heat)	Drought Rainfall variability (erratic and linked to flooding in low-lying areas) Rising temperatures (extreme heat)

A range of factors create **vulnerability** in the Maize value chain, including a very high prevalence of population undernourishment, and moderate to severe food insecurity, plus high poverty and unemployment 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). The maize value chain in Zambia is marked by a high percentage of post-harvest losses.

Stakeholders in Lusaka and Chipata added further granularity and insights to the understanding of vulnerability in the maize value chain, indicating that principal drivers of vulnerability in Zambia's maize value chain – at harvest and during post-harvest stages – are: **poor storage facilities at small-scale farm level, resulting in micro-toxin buildup and pest damage; inadequate technical skills and knowledge among farmers, about crop suitability; poor access to markets and market information (which leads to production without an assured market); poor access to climate information services; and the lack of or limited access to efficient harvesting and post-harvest technology, equipment, facilities, and infrastructure.**

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

Table 3-8- Top three climate change vulnerability factors identified for Zambia'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
Lusaka	Lack of/limited access to technology, equipment, facilities, infrastructure (especially storage) Lack of/limited access to knowledge and skills Lack of/limited access to markets and market information	Lack of/limited access to technology, equipment, facilities, infrastructure (especially storage) Lack of/limited access to knowledge and skills Lack of/limited access to markets and market information	Lack of/limited access to technology, equipment, facilities, infrastructure (especially roads) Lack of/limited access to knowledge and skills Lack of/limited access to markets and market information
Chipata	Lack of/limited access to knowledge and skills Lack of/limited access to technology, equipment, facilities, infrastructure (especially storage) Lack of / poor access to climate information services	Lack of/limited access to knowledge and skills Lack of/limited access to technology, equipment, facilities, infrastructure (especially storage) Lack of / poor access to climate information services	Lack of/limited access to technology, equipment, facilities, infrastructure (especially roads) Lack of/limited access to knowledge and skills Lack of / poor access to climate information services

In terms of **exposure**, key factors are the share of cropland area under maize, and the existing level of financial losses in the maize post-harvest value chain, as a percentage of agricultural GDP, that Zambia is already facing.

Overall, in our comparative climate change risk assessment, quantitatively the risk level of the maize value chain in Zambia scored: 47.905 out of 125, putting it at rank **2** of the 14 crop value chains similarly assessed.

Table 3-9 - 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 vigor 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, as well, cause physical damage to storage infrastructure and cause loss of stored grains (e.g., through 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 other post-harvest processes such as processing, transportation, and distribution to markets (wholesale and retail) are relatively indirect, including through acute (fast-onset) and chronic (slow-onset) damage to machinery and equipment (e.g., via weathering, rusting, decay, and other weather-related depreciation of assets), transportation infrastructure (damage to roadways, railways, bridges, e.g., melting and buckling of roads or rail tracks, warping of joints on bridges), and distribution networks (supply chain disruptions, e.g., damage to market locations from extreme weather events).

While direct attribution of climate change to post-harvest losses of maize in Zambia 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 16.9% of the maize harvest in Zambia was lost as dry-weight loss in 2022, and this averaged 17.02% over the past ten-year period (APHLIS, n.d.).

Based on decadal data from 2013 through 2022, of the various post-harvest value-chain stages (per APHLIS, 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 Zambia (in decreasing order) are:

1. **Harvesting and field drying** – an average annual loss of 6.2% of the crop
2. **Household-level storage** (by far the stage of greatest losses) – an average annual loss of 4.45% of the crop
3. **Further drying** – an average annual loss of 3.96% of the crop.

Together, these three stages represent an average annual loss of nearly 14.61% (just under a sixth) of the total losses in the maize value chain in Zambia. Out of the *post-harvest losses* in the maize value chain in Zambia, these stages account for 85.84% of post-harvest losses (i.e., the vast majority).

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 Zambia, ***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 happen) of the maize value chain are still largely linked to on-farm activities such as household storage, harvesting and field drying, it is fair to surmise that the areas in Zambia where maize is farmed are the dominant geographical locations for these losses, at these stages. Based on the map of maize growing areas in Zambia (below) (United States Department of Agriculture (USDA), n.d.), the Eastern Province (accounting for 22% of maize production in 2012-2015), the Central Province (20% in 2012-2015), and the Southern Province (18% in 2012-2015) may be prioritized for climate-responsive, risk-reduction interventions.

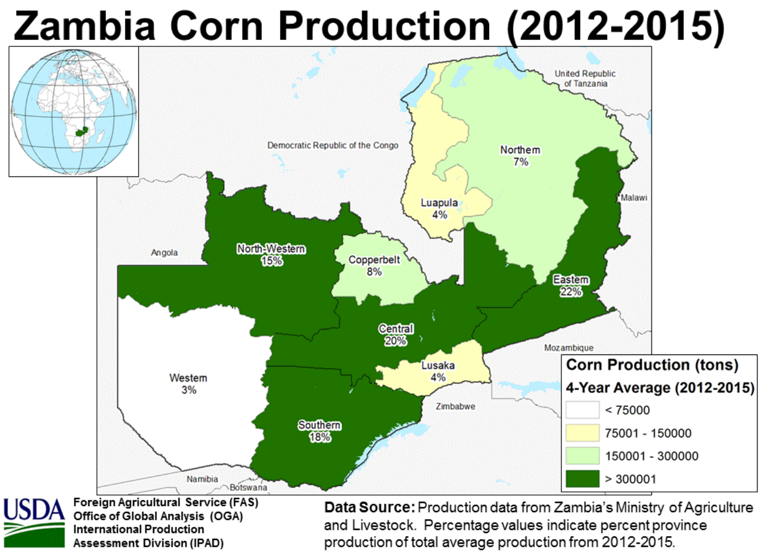


Figure 3-23 - Zambia: Maize Production by Province, 2012-2015 (USDA, FAS)

Stakeholder workshops in Zambia 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 (provinces) that should be the focus of RE-GAIN's post-harvest loss-reduction climate change solutions are:

- The Eastern Province
- The Central Province
- The Southern Province
- The Western Province
- The Northern Province

3.5.2 Soybeans

Our analysis of climate change risks to the soybean value chain in Zambia indicates that the most significant **hazards** are heavy or intense precipitation (extreme volumes of rainfall in a single day period, and the number of days with rainfall over 20 mm), and higher temperatures (most severely the number of days above 35°C, but also the increase in mean annual temperature), flooding (pluvial and fluvial), and wildfires. To a slightly lesser degree, drought and heatwaves also pose a threat.

Zambian stakeholders at the national and local levels underscored that for the soybeans value chain, climate hazards that pose the most substantial risk at harvest and during the post-harvest stages are **drought, rainfall variability (erratic), and high temperatures (extreme heat).**

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

Table 3-10 - Top three climate change hazards identified for Zambia's soybeans 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
Lusaka	Drought Rainfall variability (erratic and linked to flooding; high moisture) Rising temperatures (extreme heat)	Drought Rainfall variability (erratic and linked to flooding; high moisture) Rising temperatures (extreme heat)	Drought Rainfall variability (erratic and linked to flooding; high moisture) Rising temperatures (extreme heat)
Chipata	Drought Rainfall variability (erratic and linked to flooding; high moisture) Rising temperatures (extreme heat)	Drought Rainfall variability (erratic and linked to flooding; high moisture) Rising temperatures (extreme heat)	Drought Rainfall variability (erratic and linked to flooding; high moisture) Rising temperatures (extreme heat)

A range of factors create **vulnerability** in the soybean value chain, including a very high prevalence of undernourishment, and moderate to severe food insecurity, plus high poverty and unemployment 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 soybean value chain in particular). The dominant share (~60%) of smallholders is an important factor, but in Zambia, the soybean value chain also has a significant presence (~40%) of large commercial farmers as well (with a somewhat greater capacity to cope with shocks and stresses).

Stakeholders in Lusaka and Chipata strengthened the understanding of vulnerability in the soybeans value chain, indicating that principal drivers of vulnerability in Zambia's soybeans value chain – at harvest and during post-harvest stages – are: **poor harvesting methods due to a lack of information and knowledge; lack of access to adequate and efficient equipment, technology, infrastructure, and facilities (especially storage and processing); and poor access to climate information services.**

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

Table 5- Top three climate change vulnerability factors identified for Zambia's soybeans 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

Lusaka	Lack of/limited access to knowledge and skills Lack of/limited access to technology, equipment, facilities, infrastructure (processing, storage) Lack of/poor access to climate information systems	Lack of/limited access to knowledge and skills Lack of/limited access to technology, equipment, facilities, infrastructure (processing, storage) Lack of/poor access to climate information systems	Lack of/limited access to knowledge and skills Lack of/limited access to technology, equipment, facilities, infrastructure (processing, storage) Lack of/poor access to climate information systems
Chipata	Lack of/limited access to knowledge and skills Lack of/limited access to technology, equipment, facilities, infrastructure (processing, storage) Lack of/poor access to climate information systems	Lack of/limited access to knowledge and skills Lack of/limited access to technology, equipment, facilities, infrastructure (processing, storage) Lack of/poor access to climate information systems	Lack of/limited access to knowledge and skills Lack of/limited access to technology, equipment, facilities, infrastructure (processing, storage) Lack of/poor access to climate information systems

In terms of **exposure**, one factor that reduces the level of exposure (relative to maize) is that the share of cropland area under soybeans is comparatively modest.

Overall, in our comparative climate change risk assessment, quantitatively the risk level of the soybean value chain in Zambia scored: 25.589 out of 125, putting it at rank **10** of the 14 crop value chains similarly assessed.

Table 3-11 - 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***

The limited available literature about post-harvest losses in the soybean value chain in Zambia does not point to climatic factors as major causes of loss. According to the FAO, one of the most significant causes of loss in the value chain is hand-threshing, which damages the bean (FAO, 2023). An FAO-funded analysis highlighted that over 90% of farmers in Zambia, particularly women, use a hand-threshing method for soybeans, which consists of beating the grain or bean with a wooden stick on a hard surface (FAO, 2023). This method leads to grain/bean damage and grain/bean loss.

Nevertheless, since temperature as well as humidity and moisture are relevant to bean quality in post-harvest stages, climate change will be an important factor to take into consideration. Literature indicates that when harvesting the beans, the suggested moisture point for soybeans is between 16-18% (Santos, 2022). Ideally, harvesting is done at a time when humidity is below 15% (Santos, 2022). The goal during harvest is to remove as much water as possible, allowing better conditions for the conservation of the chemical and physiological properties of the beans (Santos, 2022). Furthermore, at the drying stage, humidity conditions should not be greater than 13%, and when storing soybeans, it is considered safe when it has water contents of 11 and 12% at the end of the drying process (Santos, 2022). If the moisture content is higher than 12%, then the stored grain can easily be attacked by pests and diseases in storage (Republic of Zambia and IFAD, 2019).

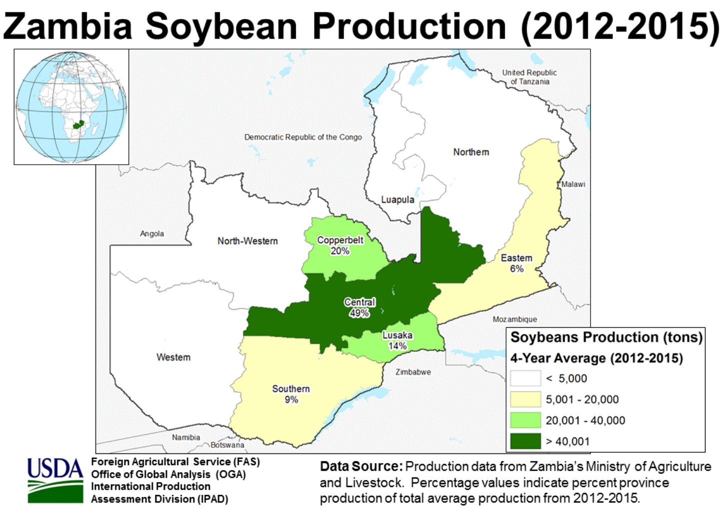
In terms of the role that temperature plays, it is recommended that temperature should not be higher than 38ºC at the end of the drying process (Santos, 2022).

While direct attribution of climate change to post-harvest losses of soybeans in Zambia 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. At a global level, the literature indicates that soybean losses occur primarily in the gathering process. The most common stages of loss are threshing, separation, and cleaning. (SDU Extension and IGrow, 2019). In Zambia too, the FAO points to threshing as a major stage of post-harvest loss (FAO, 2023). Climate does not seem to have a substantial role in threshing.

However, to the extent that some losses do occur afterwards, during drying and storage, the role of temperature and moisture conditions during drying and storage would make **climate change relevant** when planning for the future. With climate change projected to cause a rise in temperatures, plus more erratic and heavy rainfall events in Zambia, ***these stages (drying and storage) of the soybean value chain are likely at risk from climate change and thus could be prioritized for adaptation (loss-reduction) responses.***

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

Based on the map of soybean growing areas in Zambia (below) (United States Department of Agriculture (USDA), n.d.), even just prioritizing climate-responsive, risk-reduction, post-harvest loss interventions in **the Central Province** (responsible for half of the soybean production in 2012-2015) would be impactful.



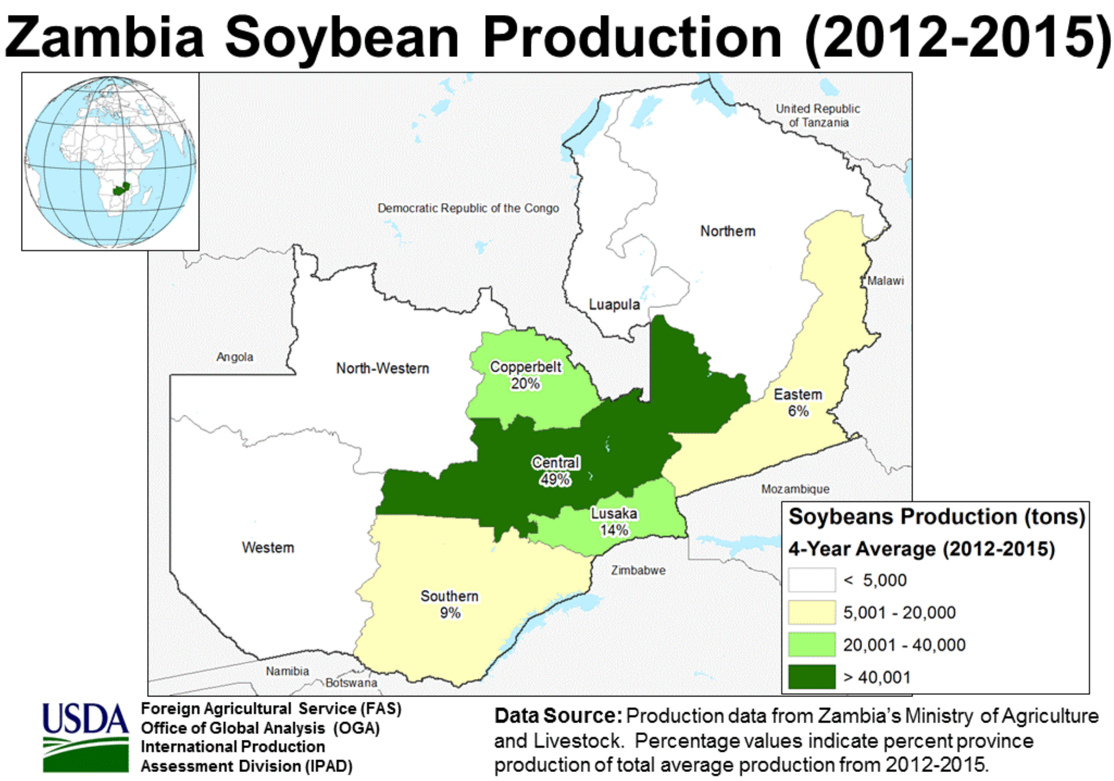


Figure 3-24 – Zambia: Soybean Production by Province, 2012-2015 (USDA, FAS)

Stakeholder workshops in Zambia 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 soybeans value chain, particularly during harvest and post-harvest stages. Insights and guidance from stakeholders suggest that the priority target areas (provinces) that should be the focus of RE-GAIN's post-harvest loss-reduction climate change solutions are:

- The Eastern Province
- The Central Province
- The Southern Province
- The Western Province
- The Northern Province

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 Zambia are presented in Table 3-12.

Table 3-12 Summary Climate Change Hazard Risk Table for Zambia 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
	Wildfires			
	Landslides			
	Cyclones			
	Sea Level Rise	N/A	N/A	N/A
	OVERALL RISK LEVEL	*HIGH*	*HIGH*	*MODERATE*
SOYBEANS	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
	Wildfires			
	Landslides			
	Cyclones			
	Sea Level Rise	N/A	N/A	N/A
	OVERALL RISK LEVEL	*MODERATE*	*MODERATE*	*LOW*

Key:

High	
Medium	
Low	

4 Climate analysis - Mitigation

4.1 Country and sectoral climate change emissions baseline

4.1.1 National emissions

Zambia presented its National Greenhouse Gas Inventory (GHGI) in their Third National Communication (Government of the Republic of Zambia, 2020) to the United Nations Framework Convention on Climate Change (UNFCCC), as well as the First Biennial Update Report (Government of the Republic of Zambia, 2020). Agriculture and land-use change, and forestry are the largest emitting sectors at ~22 million tonnes CO_2e and ~52 million tonnes CO_2e as of 2021, respectively (Figure 4-1). While Zambia's national emissions have grown steadily in the last few decades, it still contributes only 0.17% of global emissions as of 2022 (Ritchie & Roser, 2024).

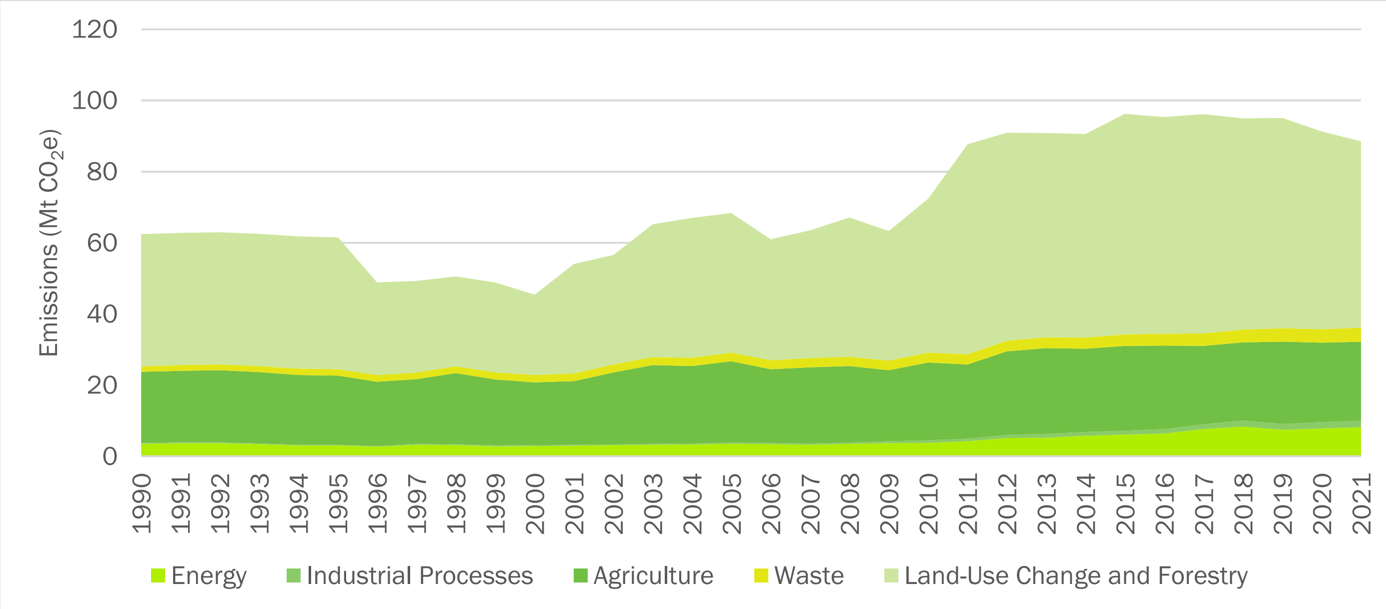


Figure 4-1 - Emissions (all GHG, $MtCO_2e$) across all sectors (total including LUCF) for Zambia (Climate Watch, n.d.)

4.1.2 Land use change

By using available land use change datasets, we can ascertain that a loss of forest cover occurred in Zambia between 1960 and 2019, with forest loss occurring over up to ~7%[2] of the land area in AGRA's target regions (see Figure 4-2 below). Cropland expanded by up to ~3% 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- and large-scale agriculture (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 Zambia (Masolele, et al., 2024)

Region	Eastern	Muchinga	North-western	Luapula	Central	Southern	Lusaka	Copperbelt	Northern	Western
Large-scale cropland	6.80%	4.20%	3.60%	4.90%	47.60%	29.30%	19.70%	9.70%	4.40%	5.30%

[2] Calculated using zonal statistics in QGIS from HILDA+ data layers

Region	Eastern	Muchinga	North-western	Luapula	Central	Southern	Lusaka	Copperbelt	Northern	Western
Pasture	<1%	3.60%	2.50%	<1%	<1%	4.20%	2.30%	<1%	<1%	11.10%
Mining	<1%	<1%	<1%	<1%	<1%	2.40%	1.40%	1.00%	<1%	<1%
Small-scale cropland	82.30%	56.50%	75.10%	73.20%	43.00%	58.50%	53.00%	73.00%	<1%	52.80%
Roads	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Other land with tree cover/ regrowth	6.70%	32.00%	13.90%	14.30%	6.00%	2.90%	15.30%	13.50%	12.90%	26.40%
Plantation forest		<1%	<1%	<1%	<1%	<1%		<1%	<1%	<1%
Coffee			<1%							
Settlement	2.20%	<1%	1.50%	4.30%	1.30%	2.00%	7.40%	1.20%	1.40%	2.00%
Water	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Oil palm			<1%	<1%						
Cashew	<1%	<1%	2.10%	1.00%	<1%	<1%	<1%	<1%	<1%	<1%
Cocoa		<1%	<1%	<1%	<1%			<1%	<1%	<1%

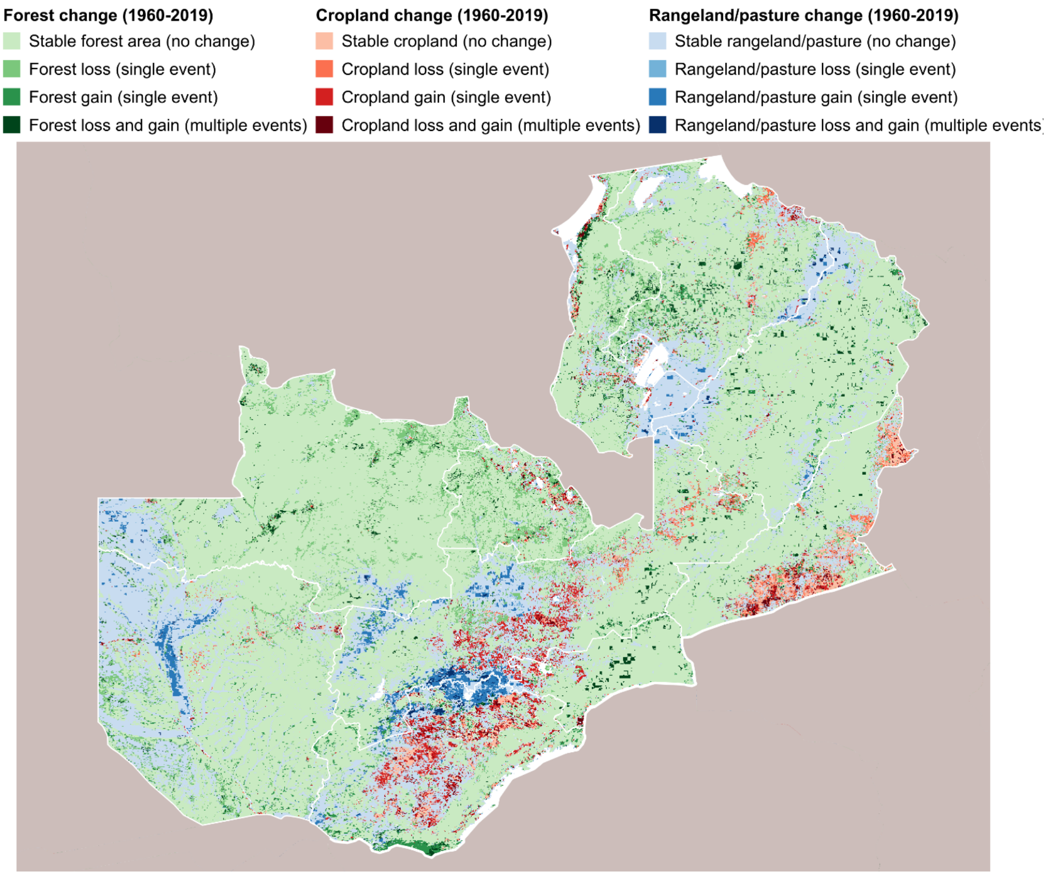


Figure 4-2 - Change in cover for land use categories forest, rangeland/pasture and cropland in AGRA target regions across Zambia between 1960 and 2019 (Land Change Stories, n.d.)

4.2 Crop value chains climate change emissions baseline

Global analyses indicate that on-farm activities and land use are the greatest contributors to emissions for commodities related to maize and soy (Figure 4-3) (Poore & Nemecek, 2018). Losses account for a significant proportion of emissions (Figure 4-3), particularly in smallholder value chains.

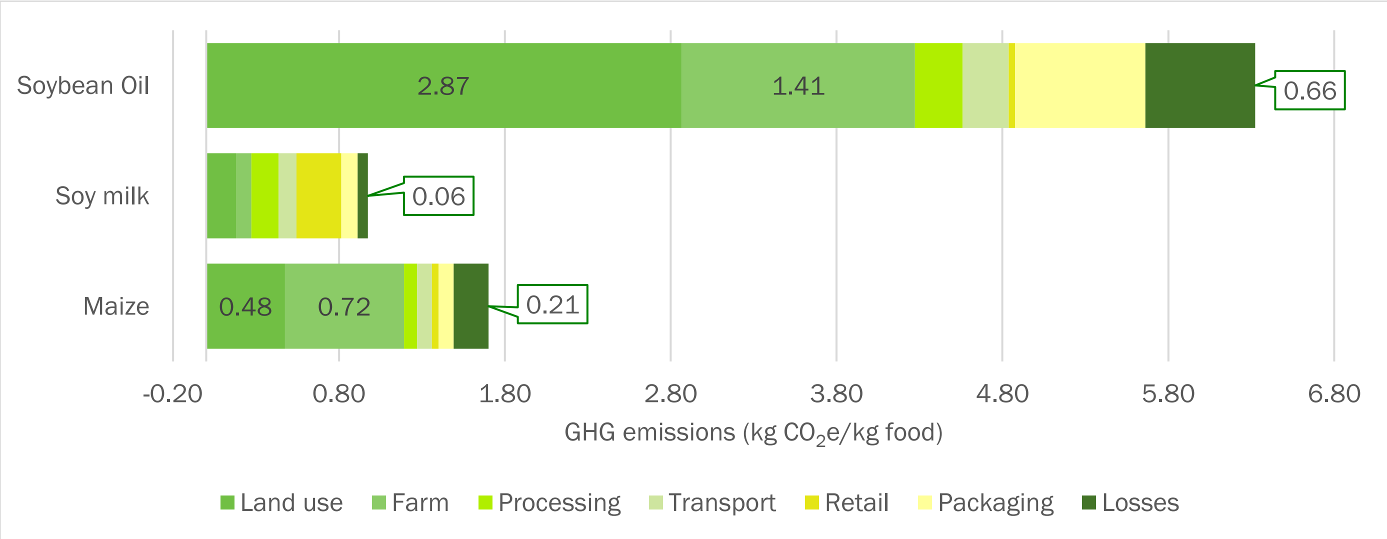


Figure 4-3 - Average GHG emissions (kg CO2e/kg food) for agricultural commodities across value chains (Poore & Nemecek, 2018)

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.

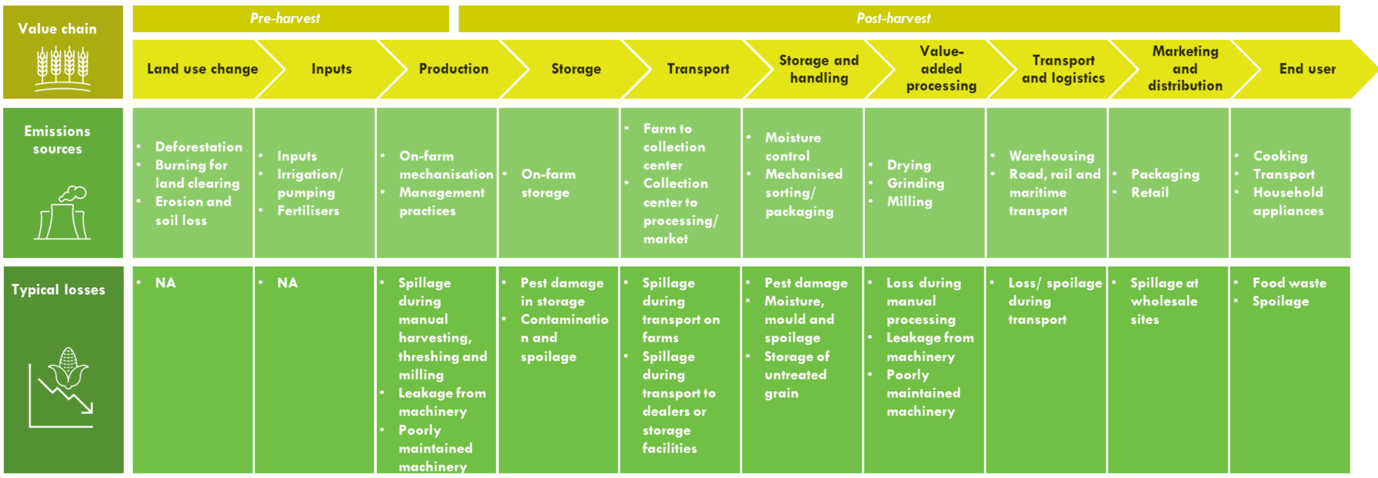


Figure 4-4 - Typical sources of emissions and food losses across agricultural value chains (Report Author's Analysis)

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 conversion of forests and other natural vegetation types to agriculture land. 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[3].

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.

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 4-2). The largest reported losses occur during the harvesting and household storage, where losses are estimated at ~6% and ~4% of total production, respectively (Table 4-2). This will be further discussed on Chapter 5.

Table 4-2 - Extent of post-harvest food loss and the main causes for maize in Zambia

Value chain stage	Losses (%)	Cause(s)	Reference
Harvesting, field drying	6.1%	N/A	(APHLIS, n.d.); (Adams & Harman, 1977)
Threshing/shelling	1.4%	N/A	
Winnowing	N/A	N/A	
Drying	3.9%	N/A	
Transport to farm	2.4%	N/A	
On-farm storage	4.4%	Damage and losses from insects and rodents	
Transport to market	1.5%	N/A	

4.2.2.1 Soybeans

On-farm post-harvest losses in the soybeans value chain occur as a result of harvesting equipment and poor storage conditions. The largest reported losses occur during harvesting and storage, estimated at up to 4 and 3% of total production, respectively (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 soybeans in Zambia

Value chain stage	Losses (%)	Cause(s)	Notes on loss values	Reference
Harvesting, field drying	4.0%	Lack of efficient harvesting equipment	Values for the harvesting/field drying and threshing/shelling phases derived from Ambler et al. (2018), as no estimates were available from either APHILIS or the FAO FLWD. Loss values for the on-farm storage phase were taken from the FAO FLWD. Values for losses during drying were derived from estimates available for Uganda from the FAO FLWD, which has been assumed to be a reasonable estimate in this case.	(FAO Food loss and waste database, 2024) (Nshimyumuremyi, 2023) (Ambler & de Brauw, 2017)
Threshing/ shelling	4.0%	Inefficient shelling machinery		
Winnowing	N/A	N/A		
Drying	1.8%	Shattering of beans		
Transport to farm	N/A	N/A		
On-farm storage	2.7%	Changes in temperature and humidity, insect damage		
Transport to market	N/A	Poor road conditions limit delivery of produce		

[3] refers to the statistic on deforestation on account of agriculture expansion

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 in Zambia could amount to 1 090 730 tCO_2e for maize and 294 075 tCO_2e for soybeans, based on smallholder production values (Figure 4-5, Table 4-4). Soybeans account for a large portion of emissions, but this may be an inflated estimate as a result of the high reported losses.

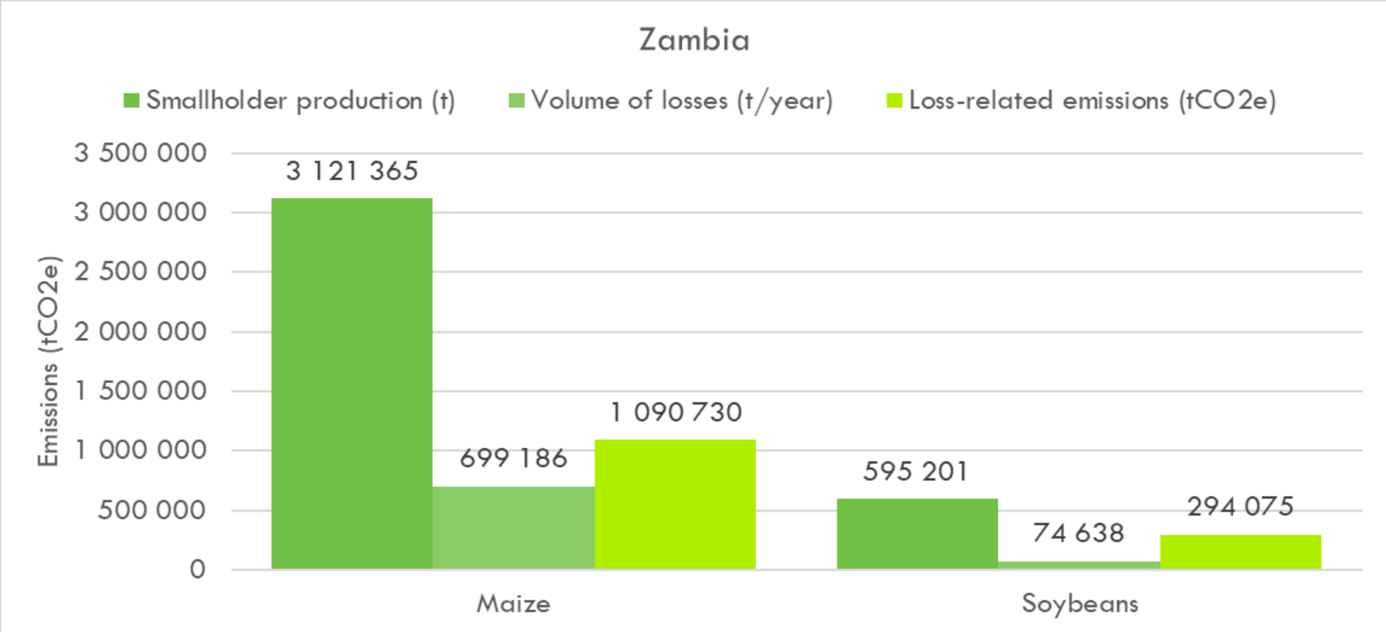


Figure 4-5 - Estimated losses across agricultural value chains for key commodities

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 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, Reay, Higgins, & Bomberg, 2016) and have been used in several studies to estimate emissions.

Table 4-4 -Estimated emissions (t CO_2e/t food) calculated using total maximum losses per commodity, total national annual smallholder production (tonnes) and emissions factors for food loss emissions published (Porter, Reay, Higgins, & Bomberg, 2016)

Country	Crop	Smallholder production (t)	Loss rate (%)	Volume of losses (t/year)	Loss-related emissions (tCO2e)
Zambia	Maize	3 121 365	22%	699 186	1 090 730
	Soybeans	595 201	13%	74 638	294 075
Total		**3 716 566**	**35%**	**773 824**	**1 384 804**

4.3 Country and sectoral climate change emissions projections

The GHG inventory developed by Zambia provides projected emissions to 2030 for key sectors under business-as-usual (BAU) and alternative scenarios. The BAU emissions projections for Zambia as stated in the Third National Communication are provided below (Figure 4-6, see also Figure 4-1 above). Emissions from the AFOLU sector are projected to increase between

2020 and 2030 under the BAU emissions scenario, reaching 132.7 $MtCO_2e$ by 2030 (Figure 4-6) (Government of Zambia, 2020).

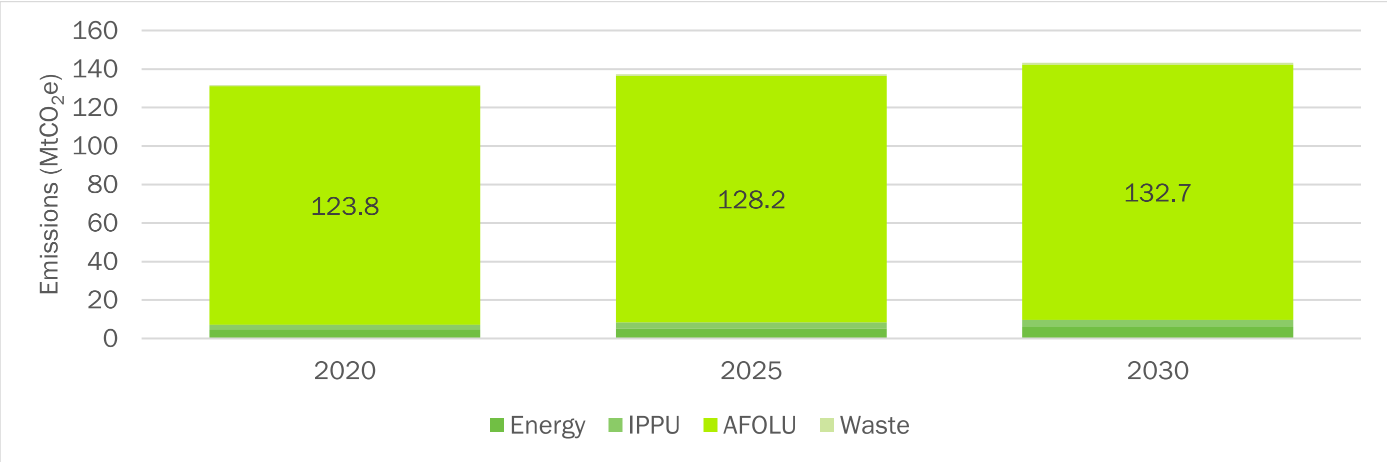


Figure 4-6 - Projected emissions across key sectors in Zambia (Government of Zambia, 2020)

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-FAO Agricultural Outlook 2023-2032, 2023).

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-FAO Agricultural Outlook 2023-2032, 2023). The COVID-19 pandemic and the war in Ukraine have exacerbated baseline food insecurity in many areas. 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-FAO Agricultural Outlook 2023-2032, 2023).

Globally, crop losses along the maize and pulses value chains 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.

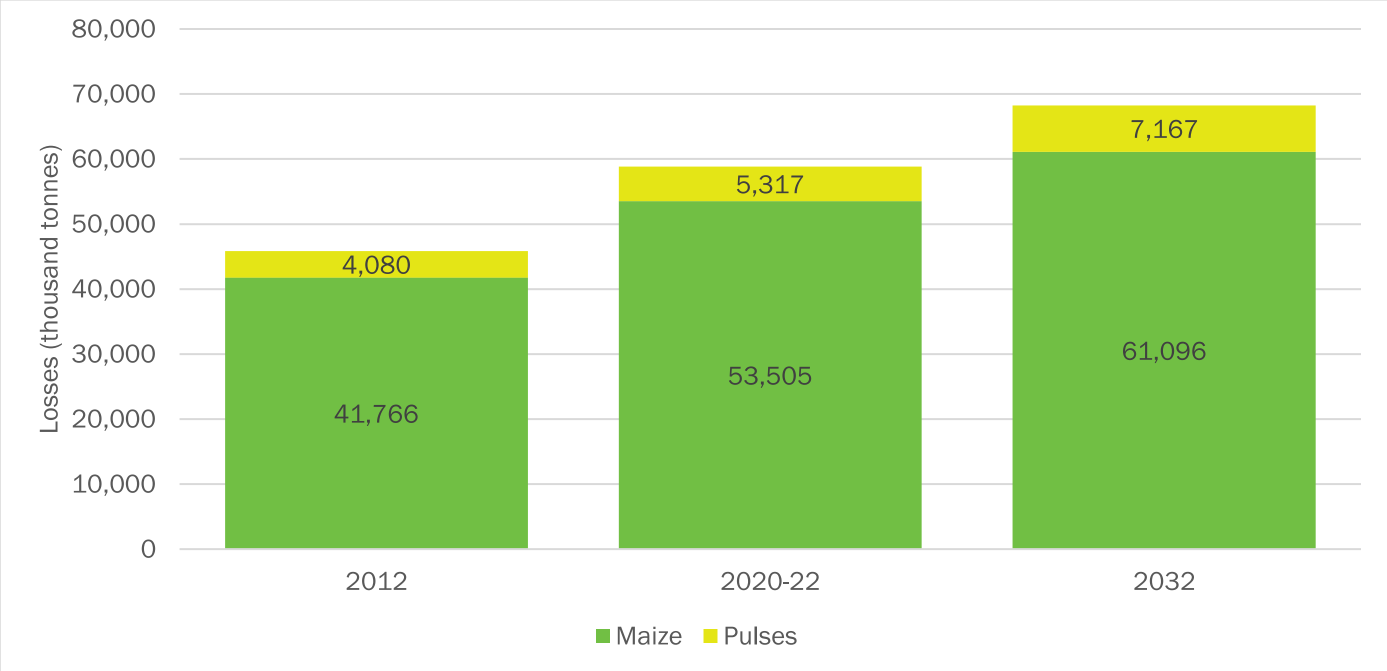


Figure 4-7 - Projected losses across global agricultural value chains for key commodities towards 2032 (OECD Agriculture Statistics, n.d.)

By using available estimates of losses as presented in Table 4-4 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 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 4-5 - Estimated emissions (t CO2e) for the year 2032 calculated using projected losses per commodity, total smallholder annual production (tonnes) and emissions factors for food loss emissions (Porter, Reay, Higgins, & Bomberg, 2016) and its sources, the OECED & FAO projections were used to calculate estimates for the production of the crops in the target countries (OECD Agriculture Statistics, n.d.). These values assume that loss estimates remain unchanged by both adaptation interventions and climate change impacts.

Table 4-5 - Estimated emissions (t CO_2e) for the year 2032 calculated using projected losses per commodity, total smallholder annual production (tonnes) and emissions factors for food loss emissions (Porter, Reay, Higgins, & Bomberg, 2016)

Country	Crop	Projected production 2032 (t)	Projected losses 2032 (t/year)	Projected loss-related emissions 2032 (tCO2e)
Zambia	Maize	3 781 778	847 118	1 321 504
	Soybeans	640 068	80 265	316 242
Total		**4 421 846**	**927 383**	**1 637 747**

Without intervention, emissions related to post-harvest losses on smallholder farms are expected to increase by between ~8% and ~21% across the target countries. **For Zambia, this could amount to** 1 321 504 **tCO_2e for maize and** 316 242 **tCO_2e for soybeans by 2032 (Table 4-5).** This presents the minimum expected losses as climate change is likely to exacerbate these numbers.

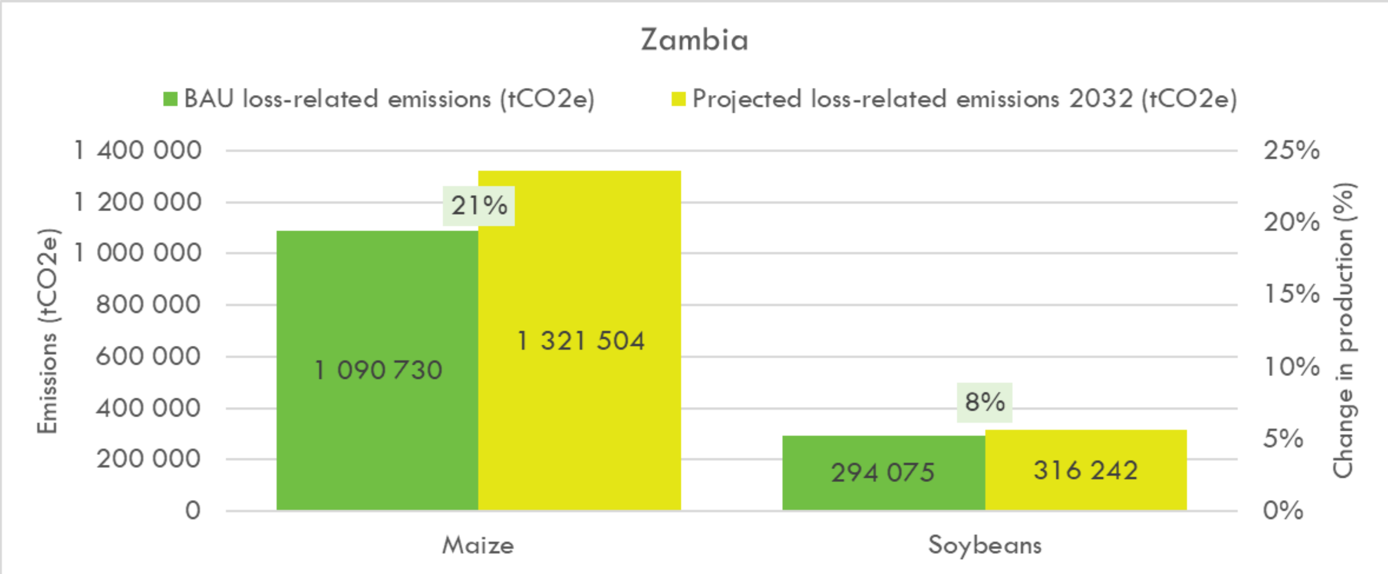


Figure 4-8 - Estimated emissions from post-harvest losses in 2022 and 2032 for key crops across Zambia, percentage values indicate projected increase in emissions

5 Design of Food Loss Reduction Solutions

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

5.1.1 Maize

Maize is the primary staple food in Zambia, accounting for around 60% of the country's caloric intake, with production primarily coming from small-scale, rain-fed (Fusillier, Alistair, Ricardo, & Chapoto, 2021). approximately half of Zambia's maize is consumed domestically in rural and peri-urban areas, while the other half is processed by industries into maize meal for household use (European Comission, 2022).

Most small and medium-sized farmers in Zambia, about 87% or 1.4 million households, grow maize, which covers 50% of their cultivated land. Despite its dominance, the average maize yield in Zambia is low at 2 tonnes per hectare, compared to a potential commercial yield of 6-7 tonnes per hectare (Bwacha, 2023).

According to the (Zambia Statistics Agency, 2020)**, with maize being cultivated in all 10 provinces in Zambia.** The Central, Eastern and Southern Provinces were the most crucial for maize growth, resulting in more than 52% of the entire national maize production (Table 5-1):

Table 5-1– National statistics on Maize production, planted area and yield rates in Zambia in 2020

Region	Production, t	Area planted, ha	Yield rate, t/ha
All Zambia	3 387 469.00	1 634 872.77	2.10
Central Province	663 681.56	295 448.71	2.25
Eastern Province	614 278.25	294 104.22	2.09
Southern Province	488 941.42	359 734.34	1.36
Muchinga Province	332 101.04	114 244.60	2.91
Northern Province	330 375.67	126 085.18	2.62
Copperbelt Province	305 672.00	101 477.86	3.01
North-Western Province	225 154.10	86 238.20	2.61
Luapula Province	182 596.23	69 490.54	2.63
Lusaka Province	132 288.88	57 388.64	2.31
Western Province	112 380.41	130 660.47	0.86

Agriculture in Zambia is concentrated in the West and Central/Southern regions, with 66% of land used for forest and game management, and 32% for agriculture (Phiri, Morgenroth, & Xu, 2019). Maize has two main harvest seasons: early harvest (April to July) and late harvest (August to October), depending on the planting time and local conditions (Japan Association for International Collaboration of Agriculture and Forestry, 2008).

Zambia faces seasonal floods, droughts, and extreme temperatures, with climate change driving maize production northwards to areas with higher rainfall (Sentinel, 2022). Despite lower production in some provinces, these areas, like Copperbelt and Muchinga, have higher yield rates of 3,01 and 2,91 t/ha respectively (ACAPS, 2024).

Maize farming in Zambia predominantly relies on manual or animal traction, with less than 5% of maize produced using motorized farming, mainly for seed production (World Bank, 2019). Harvesting is typically done manually with some larger operations using combine harvesters. Due to limited storage facilities and high storage costs, farmers often sell their maize early in the harvest season, affecting the ability of small-scale millers to buy in bulk and forcing them to purchase from aggregators later at higher prices.

In the maize harvesting process, this typically involves manual labour in Zambia, with workers using machetes or sickles to cut down mature maize plants. While some larger-scale farms use combine-harvesters, this method is less common due to limited availability and high costs. Harvesting usually occurs after the maize has fully matured during the dry season, reducing the need for field drying. Once harvested and dried, the maize cobs are transported to the farm where they are separated from the stalks by hand or with mechanized threshers (Dr. Frank Kayula, 2022).

Post-harvest practices in Zambia primarily involve shelling, packaging, and storing the grains on farms. For smallholder farmers, shelling (the removal of grains from the cob) is done manually or with small mechanical shellers. Farmers with larger maize areas (more than 3 hectares) mainly use small shellers, while large-scale operations use fully mechanized systems during harvesting. The grains are packaged in 50 kg polypropylene bags, which are often reused multiple times (Fusillier, Alistair, Ricardo, & Chapoto, 2021). The final farm gate product is maize grains packed in these 50 kg bags.

Maize can be sold directly to individual buyers from the farm or transported to aggregation depots using various methods. These paths can differ in distance and load size, depending on factors like farm size, input levels, proximity to towns or market centres, and the farmer's capacity to organize transport to mills, grain trading companies, and markets offering better prices. Indeed, during the aggregation phase, activities such as pre-cleaning and repackaging of grains may occur, and storage at aggregation depots might include fumigation. Grain handling varies from entirely manual to partially mechanized processes.

Maize milling in Zambia can be divided based on scale and technology used. There are industrial mills, which are large to medium-sized roll mills with a milling capacity of more than 1.5 tonnes per hour. Additionally, there are small-scale mills, primarily village-level operations, that use two types of machinery: hammer mills and grinding-wheel mills, often referred to simply as "hammer mills" (European Comission, 2022).

On the supply side, a notable feature of Zambia's maize market is the relatively low proportion of maize production sold by farmers, with only about half of the production being commercialized. Most farmers are small-scale, cultivating less than 2 hectares, and prioritize meeting their own food needs. As a result, commercialization is minimal for many farmers (Sentinel, 2022).This production structure significantly impacts maize market dynamics and price setting, as even small changes in production levels due to climatic or biotic hazards can greatly affect market supply. This highlights the critical role of interannual storage in market regulation.

According to (FAOSTAT, 2022), over the last 30 years (1992-2022), maize cultivation area in Zambia have been slowly increasing (Figure 5-1), starting from 661 305 ha in 1992 and resulting in 1 115 489 ha in 2022. In the meantime, both yields and production volumes varied significantly from year to year, mainly impacted by environmental factors and cultivation techniques.

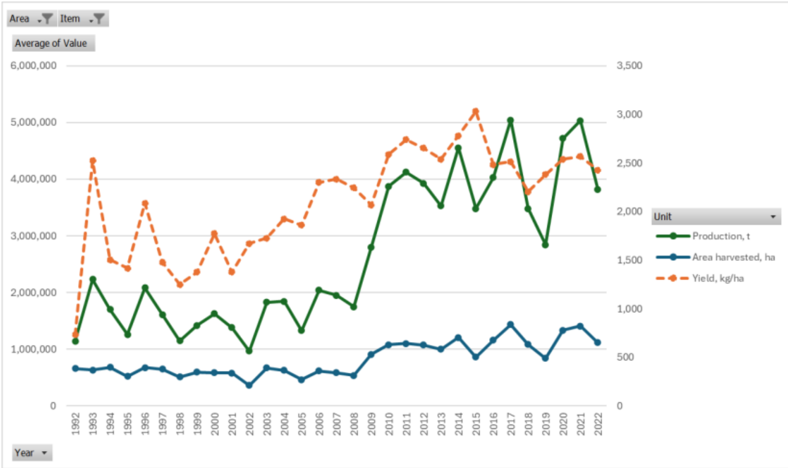


Figure 5-1 - Maize production, harvest area and annual yields in Zambia, 1992-2022 (FAOSTAT, 2022)

Considering the data available and the focus of this programme, improving yields, and reducing post-harvest and storage losses loss along the maize value chain in Zambia has the potential to release pressure on land and reduce forest degradation triggered by cropland expansion.

From 2011 to 2021, Zambia has been successful in producing enough maize to satisfy its domestic needs and consumption (

Table 5-2, Figure 5-2), and even export part of the production abroad (FAOSTAT, 2022).

Table 5-2 – Maize production, domestic supply and consumption, export and losses in Zambia, 2011-2021 (FAOSTAT, 2022)

Year	Production, 1000 t	Domestic supply quantity, 1000 t	Export quantity, 1000 t	Food supply quantity (kg/capita/yr)	Losses, 1000 t
2011	3 020	2 026	525	110.68	91
2012	2 853	2 103	730	110.83	86
2013	2 533	2 431	176	127.77	76
2014	3 351	2 729	96	136,67	101
2015	2 618	2 636	727	128.70	79
2016	2 873	2 763	527	131.07	86
2017	3 607	2 795	353	126.22	108
2018	2 395	2 730	60	123.72	72
2019	2 004	2 645	46	107.07	162
2020	3 387	2 671	121	97.37	102
2021	3 620	2 598	265	98.69	109

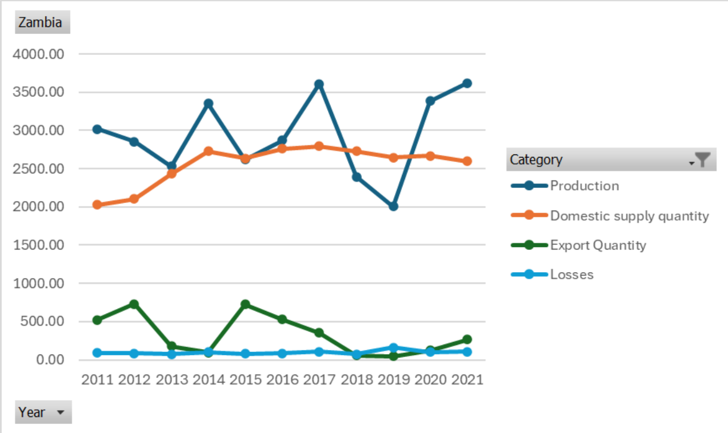


Figure 5-2 - Maize production, domestic supply, export quantities and losses, 1000 t, 2011-2021 ((FAOSTAT, 2022)

In Zambia, the key meteorological factors impacting agriculture are changes in temperature and precipitation (Mwongera, et al., 2020). Rising temperatures are anticipated to severely affect agricultural output by subjecting crops to heat stress. Additionally, maize losses are often due to inadequate long-term storage facilities. The average number of growing days during the wet season has been declining, and the intensifying heat stress is expected to further reduce both animal and crop production.

Maize food loss data from different sources are presented in Table 5-3 below.

Table 5-3 - Comparison of Maize food losses in the different stages of the value chain in different studies

Value chain stage	APHLIS (APHLIS, n.d.)	(Fusillier, Alistair, Ricardo, & Chapoto, 2021)
Harvesting/ field drying	6.4%	
Further drying	4%	
Threshing and Shelling	1.3%	
Transport from field	2.4%	
Household-level storage	2.5%	10%
Transport to market	1.7	
Market storage	N/A	
Overall	18.3%	

Table 5-3 indicates that the most critical value chain stage in terms of food losses is harvesting, household (farm level) storage, and drying. A general overview of the maize value chain in Zambia, covering key stages, processes, stakeholders, climate data, and potential solutions to reduce food losses are presented in the Table 5-4.

Table 5-4 - Overview of Maize food losses in Zambia in the different steps in the value chain, relevant parameters, and suggested solutions

FSC Stage/ process	Processes	% losses (APHLIS)	Cause of losses	Affected stakeholders	Climate aspects	Suggested solutions
Harvesting						
Reaping	Cutting/gathering the cobs, manually or using mechanical harvesters	6.1%/ 6.4% Combined		Farmers	Heat stress for workers/farmers and animals, increased humidity/ moisture of crops and fungi development	Capacity building training on harvesting techniques and harvesting tools
Post-harvest drying	Field drying in stooks	4%		Farmers	Rains, winds	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	
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	
Drying	Additional drying using cribs, tarpaulins, and similar solutions	4%	Mold, insects, rodents, livestock foraging	Farmers	Rains, winds, temperature	Plastic sheets and tarpaulins, rectangular cribs
On-farm storage		2.5%	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	Not Reported	Spillage, contamination	Millers		

FSC Stage/ process	Processes	% losses (APHLIS)	Cause of losses	Affected stakeholders	Climate aspects	Suggested solutions
	fully mechanised small-scale and industrial mills		with foreign materials			
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%		Aggregators/ collectors and traders		Plastic hermetic bags; non-hermetic polypropylene bags
Grading and packing	Sorting, pre-cleaning, re-packaging and packaging	Not Reported		Collectors and traders		Plastic hermetic bags; non-hermetic polypropylene bags
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)	Not Reported	Spillage, qualitative losses	Traders		
Secondary processing	Further processing into roller meal, flour, animal feed, products for snack and brewing industry, etc.	Not Reported		Secondary processors		Adaptation of the milling process?

5.1.2 Soybeans

Soybeans were introduced to Zambia in the 1930s and are primarily cultivated by commercial farmers who account for 85% of the country's soybean supply. These farmers typically use high-input farming methods, including irrigation, resulting in relatively high yields. Zambia's soybean production is largely driven by the rapidly growing poultry sector and the expanding oil industry. In Zambia, soybeans are processed into oil, soybean chunks, and soybean meal. By-products such as soybean cake are utilized as animal feed, either directly or processed with other ingredients into animal feed stock (Zambia Agribusiness Society, 2019).

The main processors of soybeans in Zambia are global industries with a current capacity to crush 360 000 metric tonnes of soybeans per year. Additionally, the government of Zambia is promoting soybeans as a cash crop among small-scale farmers (Siamabele, 2019). In Zambia, soybean cultivation involves small to medium-scale farmers, typically managing land plots of up to 20 hectares (IGC, 2022). The government has identified soybeans as a value chain with significant potential for improving nutrition, generating income, and creating job opportunities, particularly for women and youth, due to the rapidly growing market

Although soybeans are grown throughout Zambia, major production areas include the Central, Eastern, Copperbelt, Lusaka, and Southern provinces, which account for 95.02% of the total soybeans grown in the country (Mtisunge B. M., 2023), (USDA: Foreign Agricultural Service, 2024). The planting season for soybeans in Zambia lasts from mid-November to mid-December, with harvest starting in mid-April and lasting until mid-June (USDA: Foreign Agricultural Service, 2024).

Since 1992, the harvested area for soybeans in Zambia has increased more than 16-fold, from 22 786 hectares in 1992 to 374 713 hectares in 2022, with production increasing 68-fold (FAOSTAT, 2022) (Figure 5-3). Between the 2011/12 and 2020/21 growing seasons, the cultivated area for soybeans increased by 24%, and production yields increased by 20% (Figure 5-4). However, there was a significant drop in 2018 due to drought conditions and low producer prices from the previous season.

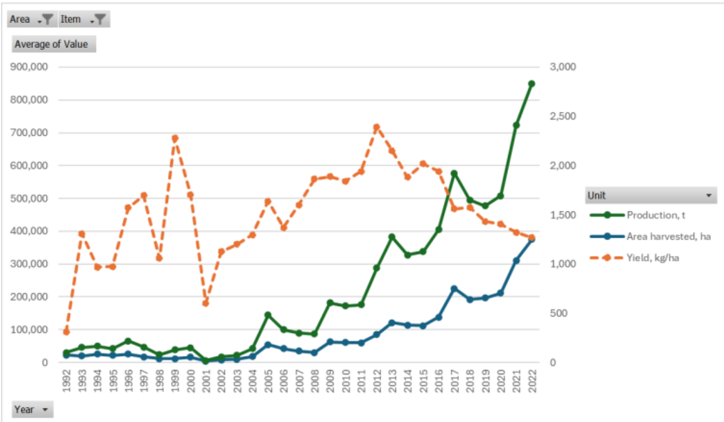


Figure 5-3 - Soybeans production, harvested area and annual yields in Zambia, 1992-2022 (FAOSTAT, 2022)

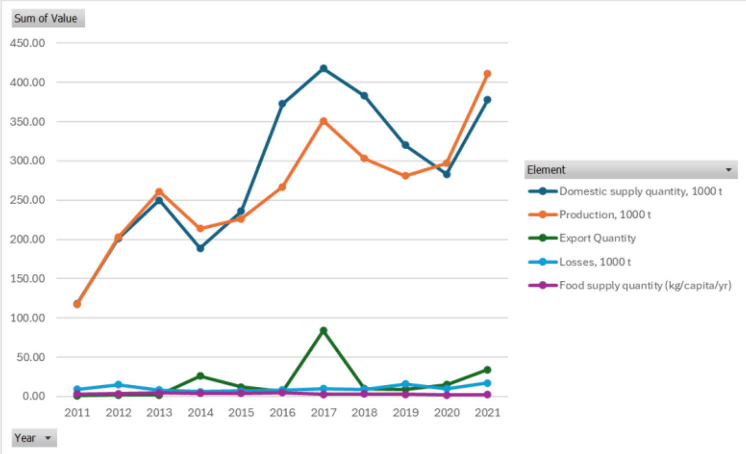


Figure 5-4 - Soybeans domestic supply, production, export, losses and per capita consumption in Zambia, 1992-2022 (FAOSTAT, 2022)

According to Zambia's Ministry of Agriculture, soybean harvesting should commence when 95% of the leaves turn yellow to brown. Delayed harvesting can lead to pod shattering, causing yield losses. Harvesting is typically done by plucking the plant from the soil. Hand harvesting, although labour-intensive, ensures better seed quality, while larger plots may use combine harvesters. Smallholder farmers can co-own such machines for labour-saving purposes and commercialization. Depending on the variety, soybean yields range from 2 to 4 tonnes per hectare (Zambia Ministry of Agriculture/IFAD, 2019)

Post-harvest activities are categorized into primary and secondary processing. Primary processing includes threshing, separation, grading, sorting, packaging, transportation, marketing, and storage, while secondary processing involves preparing soybeans for direct consumption (Zambia Ministry of Agriculture/IFAD, 2019)

Threshing involves removing grains from the pods, commonly done manually by piling harvested plants and beating them lightly. This method, though laborious, is prevalent among smallholder farmers due to the high cost of threshing machines, which can be around 5 000 USD (Mtisunge B. M., 2023). The result is often grains mixed with debris, soil, and broken soybeans, which are then cleaned through winnowing to minimize exposure to pests and diseases.

Cleaned soybean grains are dried to a moisture content of 10-12% by exposure to sunlight. High moisture content can lead to pest and disease attacks during storage. Before storage, grains are packaged in polythene or cotton fibre bags and stacked on raised wooden platforms to avoid direct contact with the floor (Zambia Agribusiness Society, 2019).

Smallholder soybean production faces several constraints, including limited crop management systems due to inadequate extension support, restricted access to mechanization due to high costs, capital constraints, poor post-harvest handling, and high input costs (particularly herbicides) (IAPRI, 2021).

The most critical stages for post-harvest food losses in the soybean value chain in Zambia are threshing and storage. Losses are attributed to insufficient handling practices, inadequate infrastructure, and theft. Over 90% of farmers, especially women, use hand-threshing methods, leading to grain damage and loss. This method also limits the area cultivated, as planting decisions are based on the physical capacity for harvesting and packaging (FAO, 2023).

While there is no publicly available data on post-harvest losses at each value chain stage, overall losses in the soybean value chain in Zambia are estimated to be between 8% and 10-20%, depending on the adoption of improved post-harvest technologies and practices (FAO, 2023). The overview of soybeans food losses in Zambia in the different steps in the value chain, relevant parameters, and suggested solutions are provided in Table 5-5.

Table 5-5 - Overview of soybeans food losses in Zambia in the different steps in the value chain, relevant parameters, and suggested solutions

FSC Stage/ process	Processes	CLP/LLP	Cause of losses	Affected stakeholders	Climate aspects	Suggested solutions
Harvesting						
Harvesting/ cutting	Cutting plants close to the ground using combine harvesters or manual tools			Farmers	Heat stress for workers/farmers and animals, increased humidity/ moisture of crops	Capacity building trainings on harvesting techniques and harvesting tools
Threshing, shelling and winnowing	Manual or mechanical shelling, using manual and mechanical shellers	CLP	Mechanical damage	Farmers	Rains, winds, temperature	
Hauling	Transport from the field to the farm by using various vehicles			Farmers	Rains, winds	
Post harvest processes (on-farm)						
Cleaning and drying	Drying using tarpaulins, dryers, and similar solutions		Mold, insects, rodents	Farmers	Rains, winds, temperature	Plastic sheets and tarpaulins, solar dryers, etc.
Sorting and grading	Sorting, grading, cleaning			Farmers		
On-farm packaging and storage	Packaged in polythene or cotton fibre bags, stacked on raided wooden platforms to avoid direct contact with the floor. Potentially also branded	CLP	Mold, insects, rodents	Farmers	Heat/ high temperatures	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 and grain collection; transportation to collection centres/ aggregation depot/ markets using vans and trucks of various capacity			Aggregators/ collectors and traders		Plastic hermetic bags; non-hermetic polypropylene bags

FSC Stage/ process	Processes	CLP/LLP	Cause of losses	Affected stakeholders	Climate aspects	Suggested solutions
Storage	In bulk and/or in bags	CLP	Spillage, qualitative losses	Storage companies, warehouses		Plastic hermetic bags, non-hermetic polypropylene bags. Insecticides/ fumigation
Processing	Processing into cooking oil, margarine, soya milk, soya flour, soybean cake/animal feed, soybeans chunks and soybean meal, etc.			Secondary processors		

5.2 SHORT-LIST OF FOOD LOSS REDUCTION SOLUTIONS (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 Zambia. RE-GAIN Programme aims to increase awareness of smallholder farmers in Zambia 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 Zambia 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 Zambia. The proposed FL-RS in those subchapters have been short-listed considering the specific context of Zambia 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 Zambia

	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.	**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.

	Awareness Raising	Capacity building
	5. **Cross-cutting themes**: climate change awareness, climate smart agriculture, farm management, marketing, product quality management, access to finance, gender and youths, etc.	• 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 • 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 Zambia, 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 Zambia, 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 Zambia.

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 and 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 5-5 below.

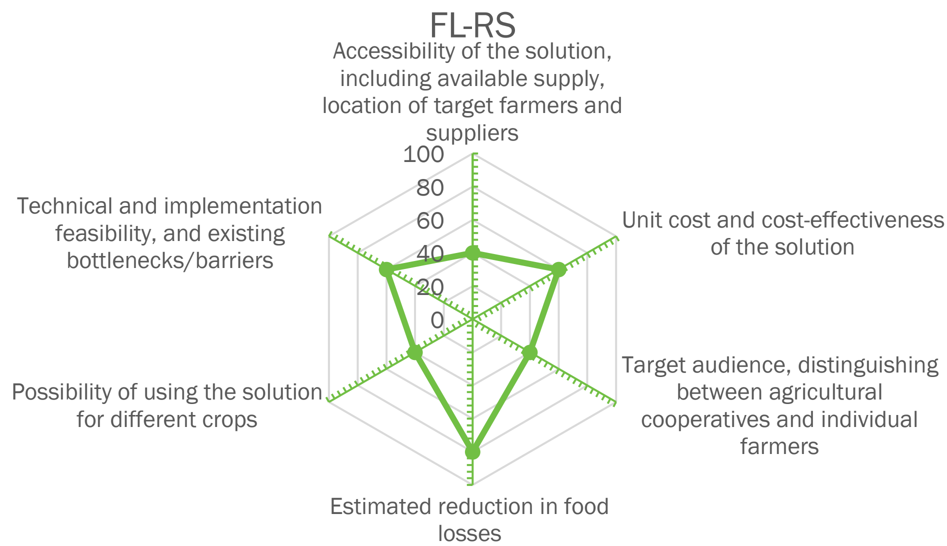


Figure 5-5 - FL-RS evaluation matrix

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, 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, 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 5-4.

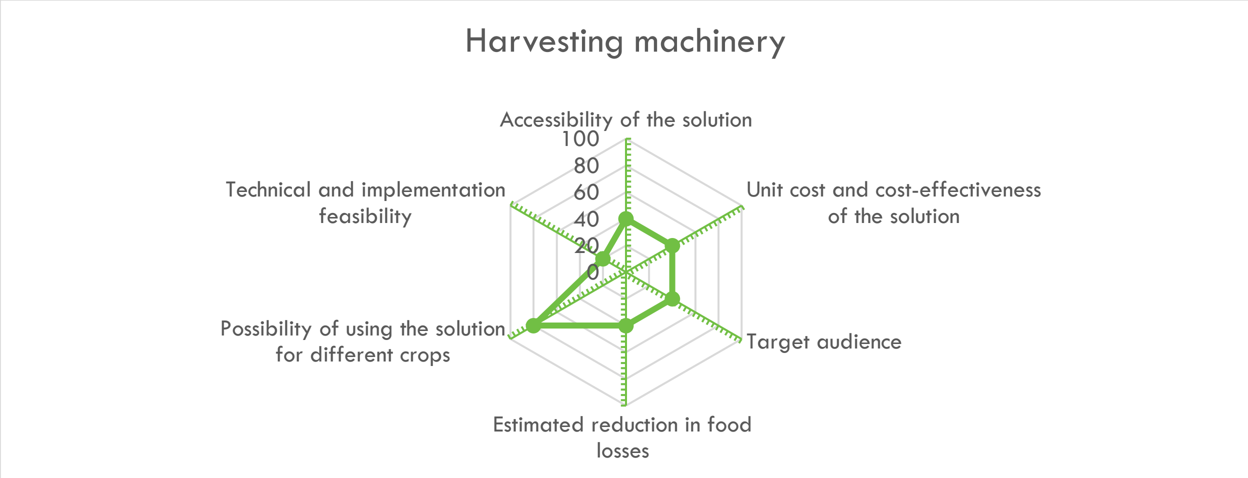


Figure 5-6 - FL-RS evaluation for harvesting machinery

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, 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, 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, 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, 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, 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 5-7.

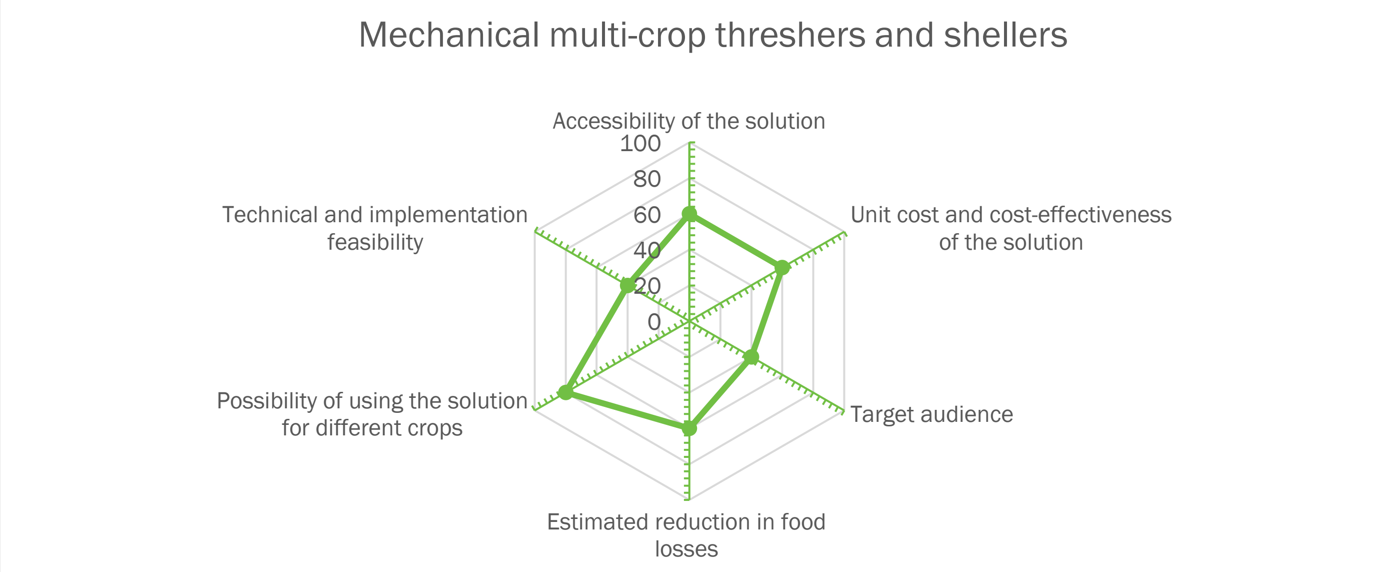


Figure 5-7 - FL-RS evaluation for mechanical multi-crop threshers and shellers

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, 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, 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, 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 5-8.

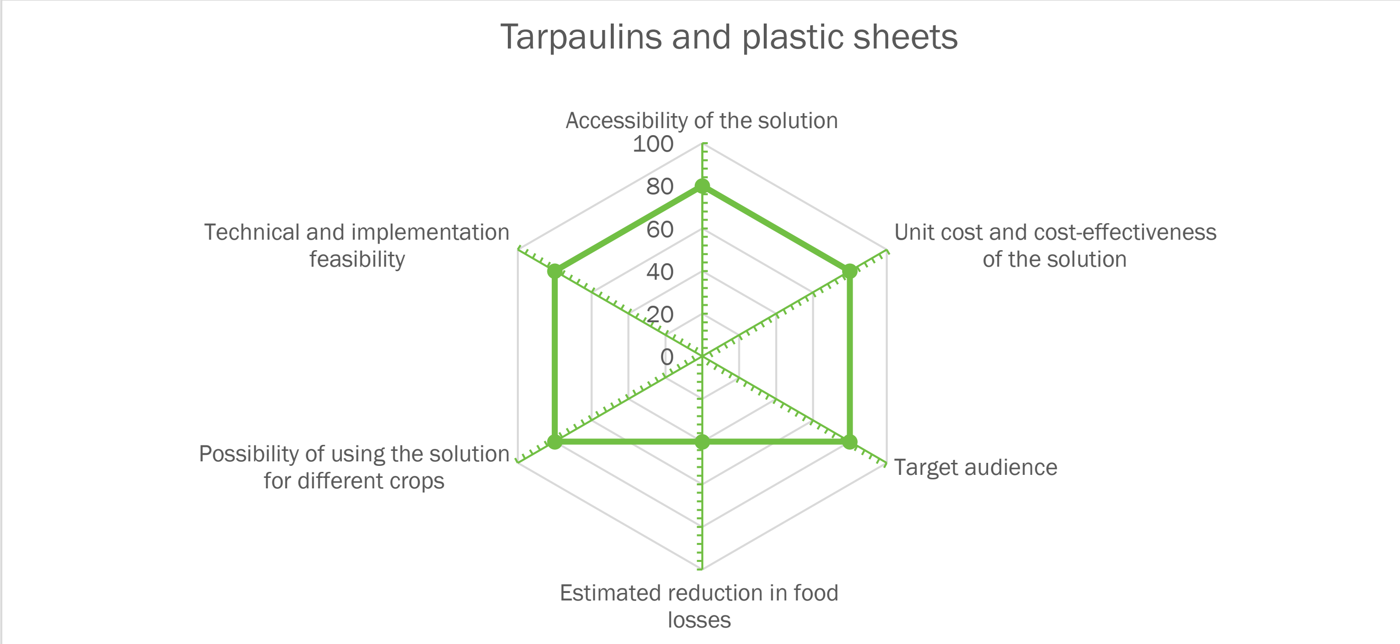


Figure 5-8 - FL-RS evaluation for tarpaulins and plastic sheets

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 5-9.

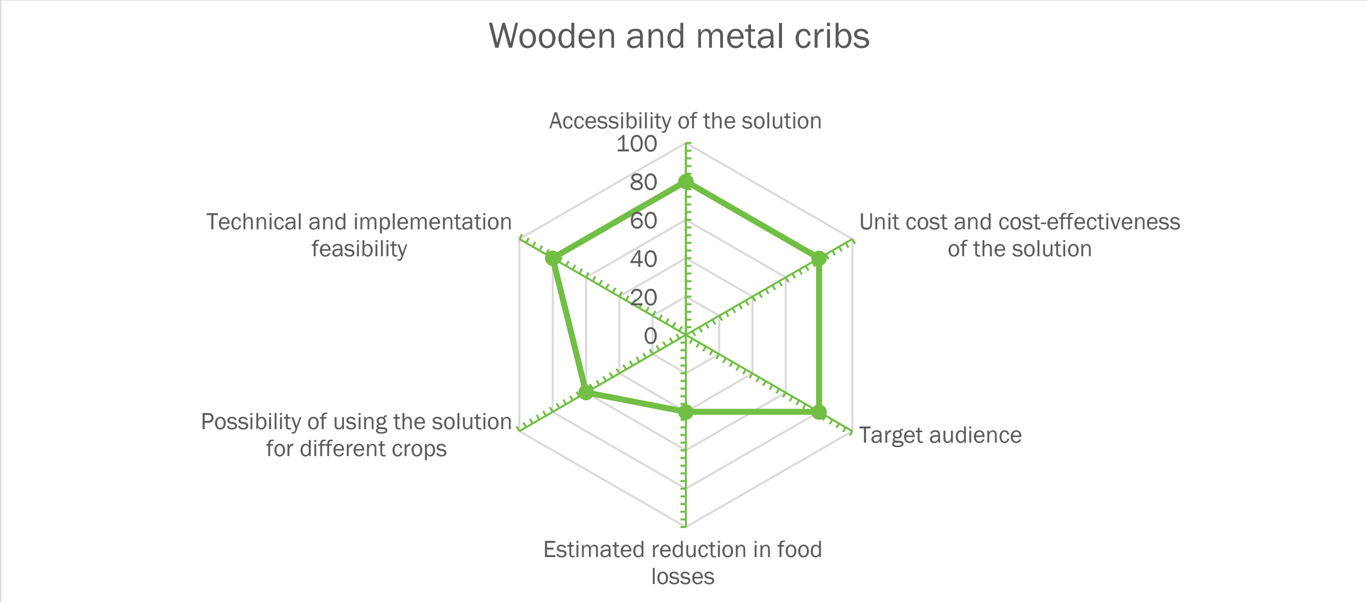


Figure 5-9 - FL-RS evaluation for wooden and metal cribs

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, 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, 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, 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, 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 5-10.

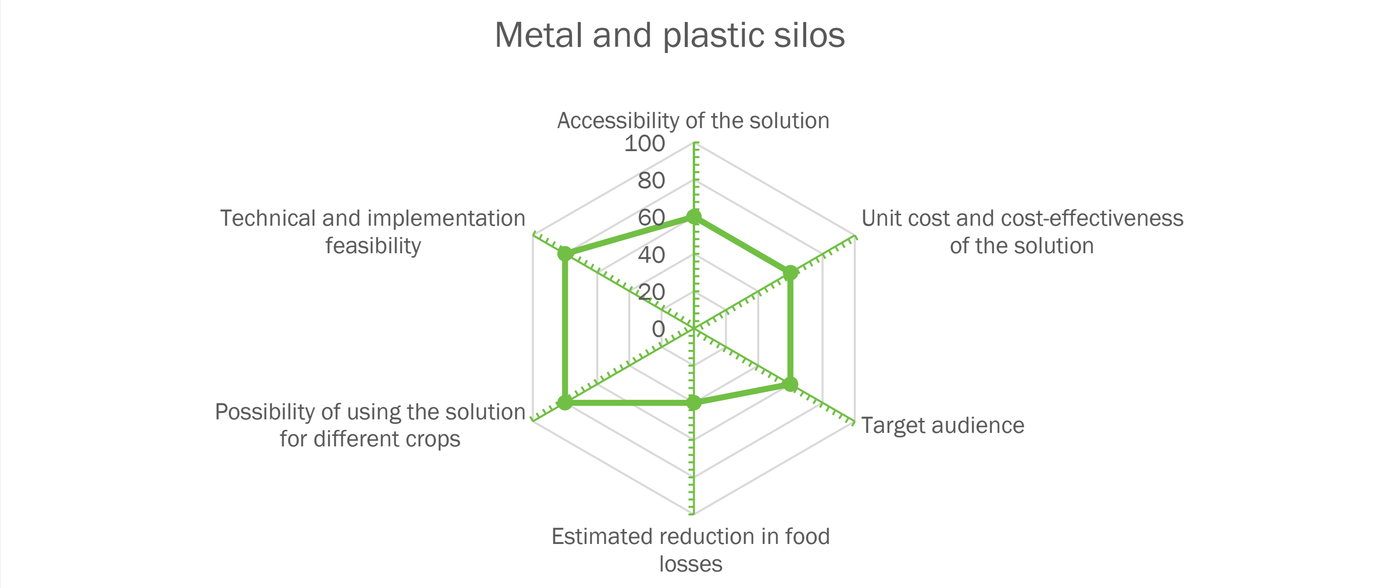


Figure 5-10 - FL-RS evaluation for metal and plastic silos

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, 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, 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, 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, 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, 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, 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, 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 5-11.

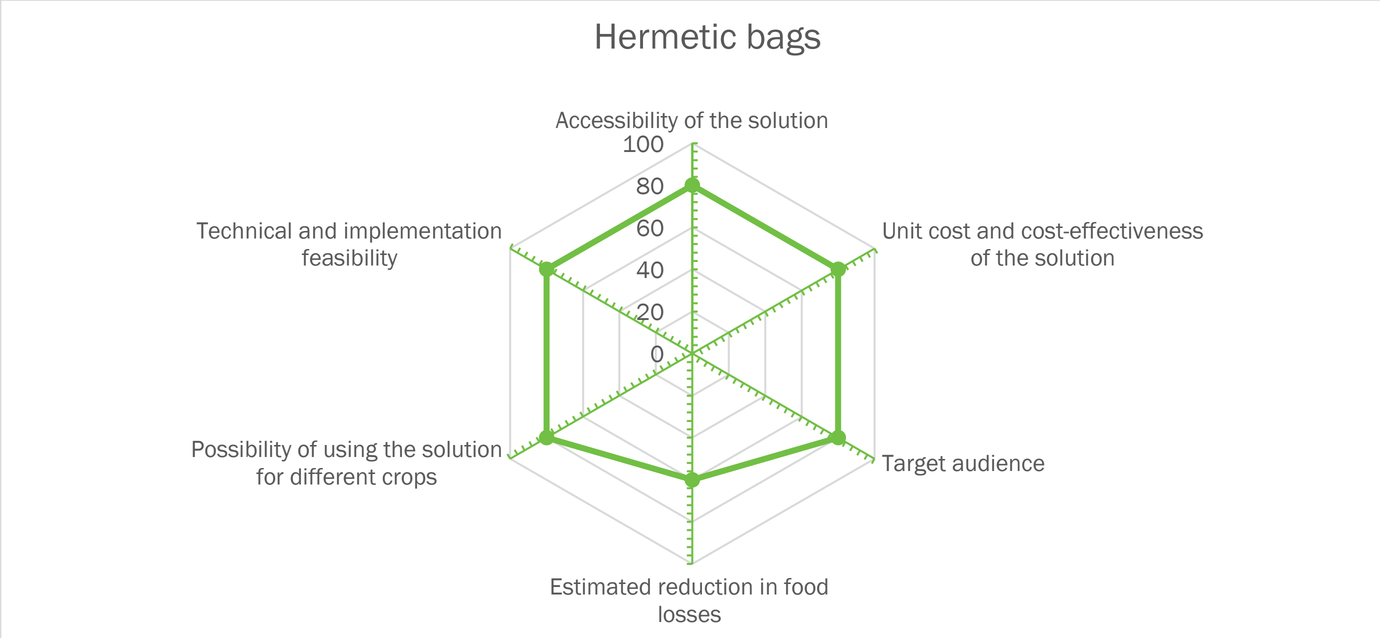


Figure 5-11 - FL-RS evaluation for hermetic bags

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, 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, 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, 2020).

The evaluation of moisture meters is provided in Figure 5-12.

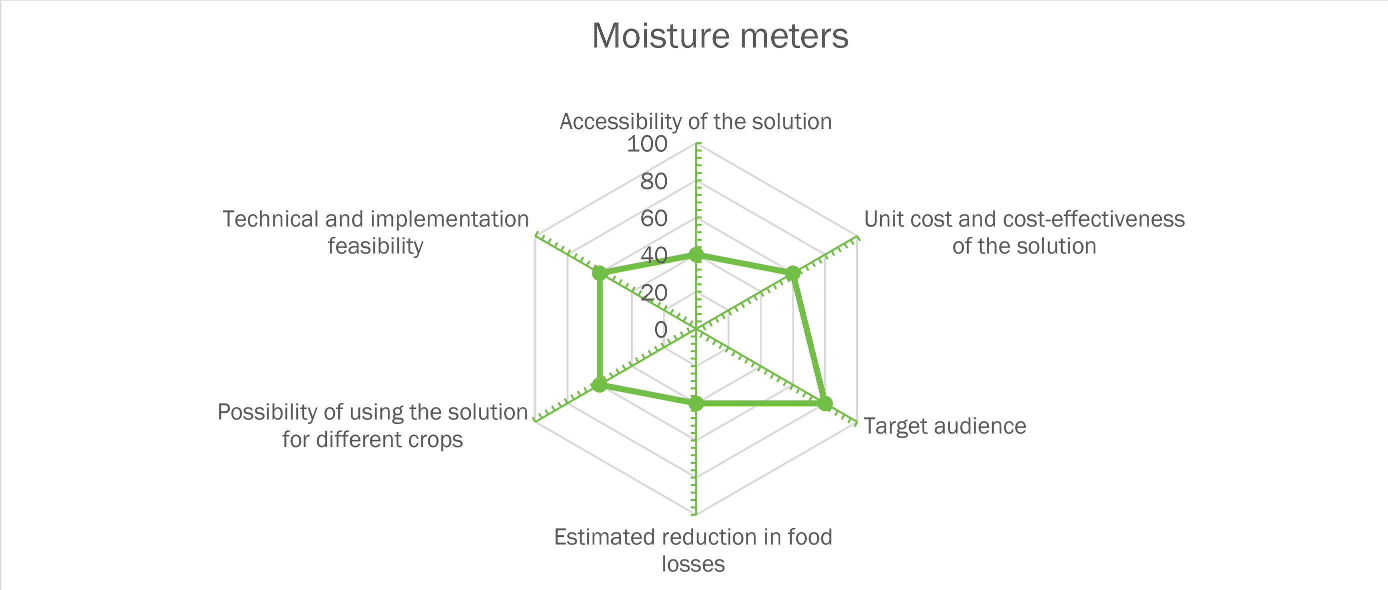


Figure 5-12 - FL-RS evaluation for moisture meters

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, 2018).

The evaluation of storage structure is provided in Figure 5-13.

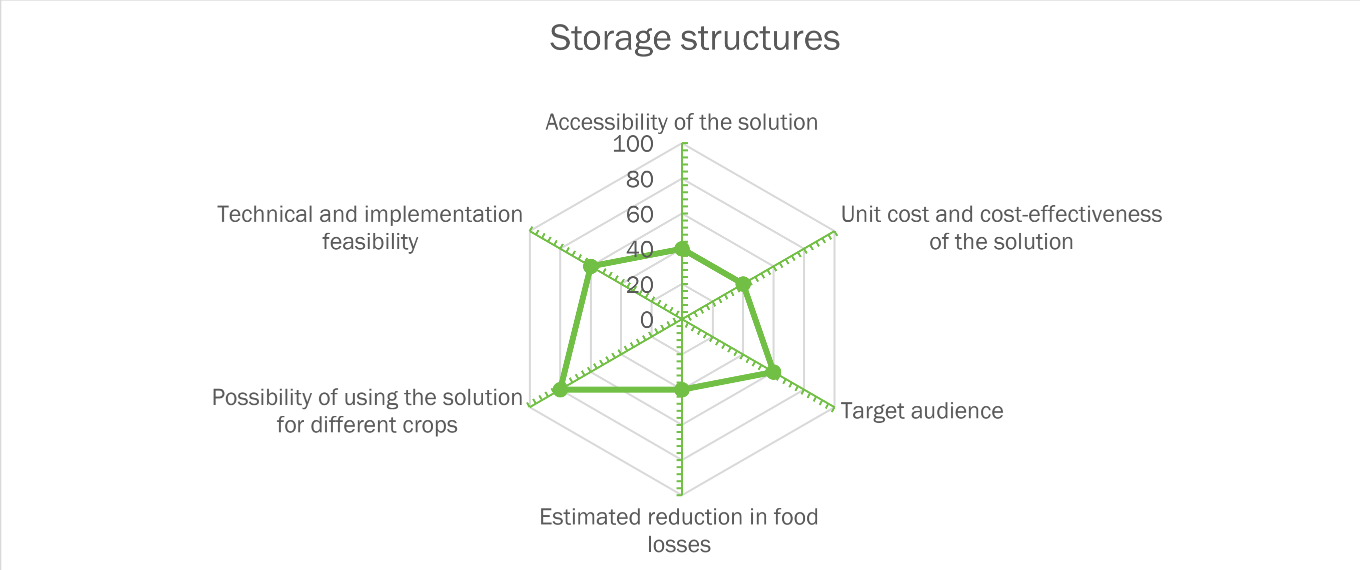


Figure 5-13 - FL-RS evaluation for storage structures

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, 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, 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 5-14.

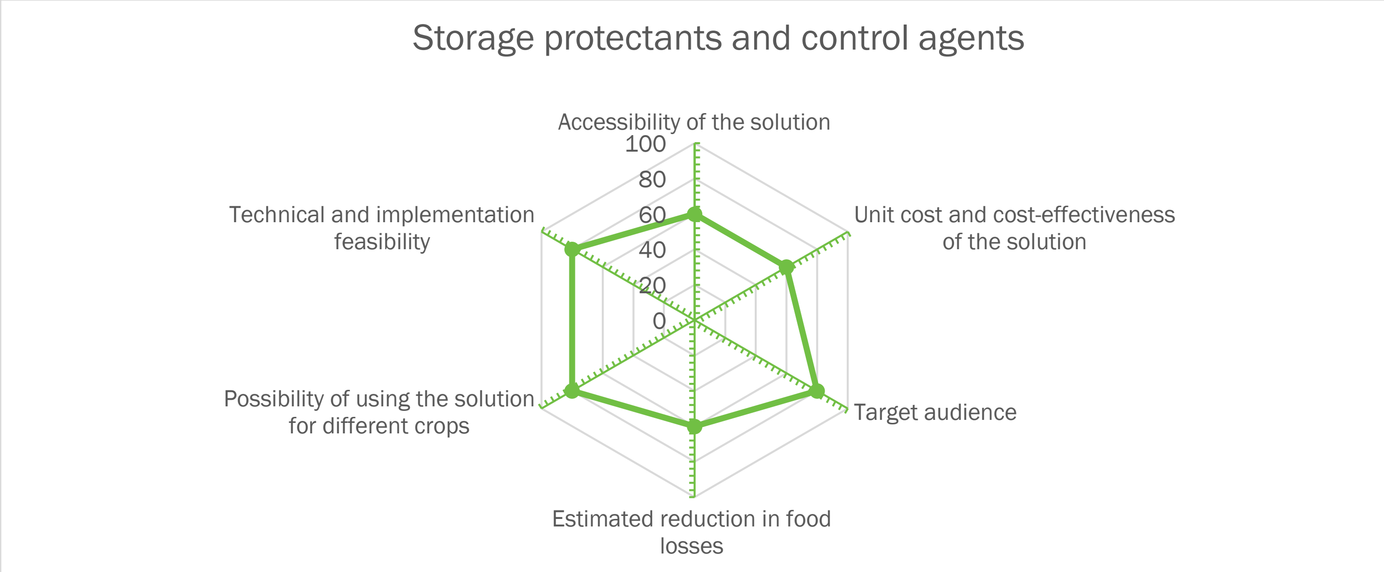


Figure 5-14 - FL-RS evaluation for storage protectants and control agents

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, 2015). For example, use of improved packaging materials for transporting beans cut postharvest losses by nearly half, from 35% to 18% (Adejumo, 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 5-15.

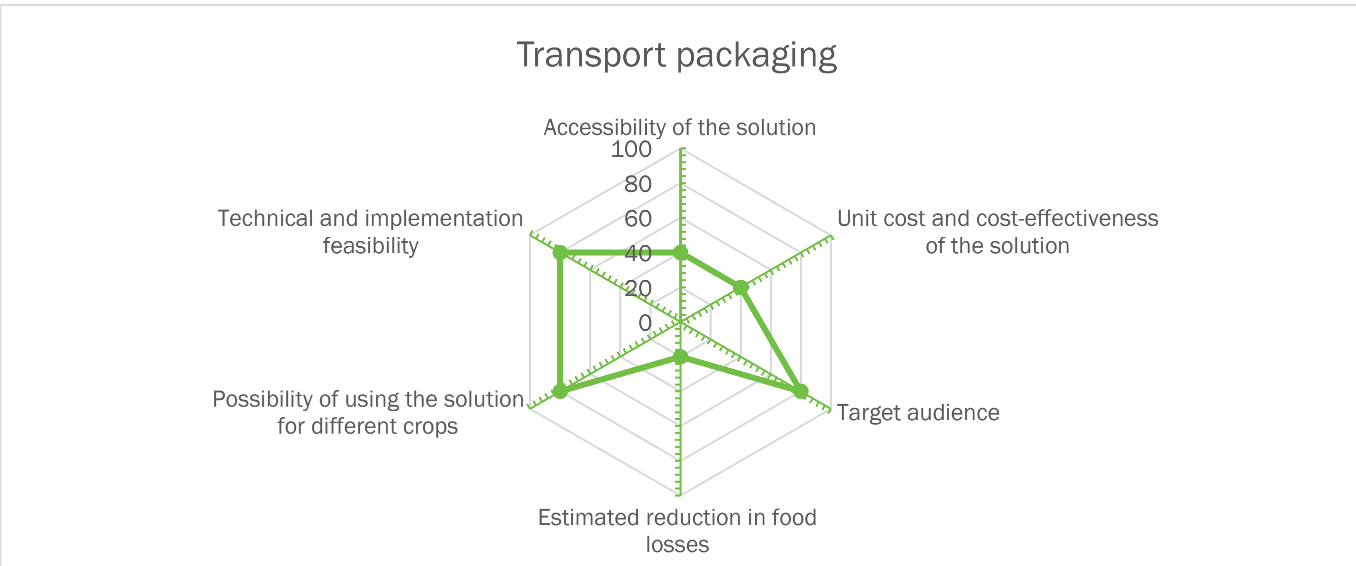


Figure 5-15 - FL-RS evaluation for transport packaging

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, 2020); (Mutungi, 2023); (Muhammad Yasin, 2019); (Aparna Kumari, 2023); (Mathanker, 2014)
Mechanical multi-crop threshers and shellers	**10-30%** *Sources:* (Amponsah, 2017); (FarmBiz Africa, 2020); (Getachew, 2022); (Soybean Innovation Lab, 2016)
Tarpaulins and plastic sheets	**10-20%** *Sources:* (Hodges, 2011); (Grolleaud, 2002); (Affognon, 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, 2019); (De Groote H. K., 2013)
Hermetic and other plastic bags	**20-30%** *Sources:* (Williams, 2017); (De Groote H. K., 2012); (Koskei, 2020)
Moisture meters	**Up to 25%** *Sources:* (Hossain, 2016); (Koskei, 2020)
Storage structures	**Up to 15%** *Sources:* (Befikadu, 2014); (FAO, 2014); (Ansah, 2018)
Storage protectants and control agents	**30-40%** *Sources:* (Tefera, 2011); (Abass, 2014)
Transport packaging	**10-15%** *Sources:* (Affognon, 2015); (Adejumo, 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 for Zambia, namely:

- Solutions that respond to the identified climate risks in the maize and soybeans value chains
- 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 maize and soybeans value chains

In terms of climate risks, both maize and soybeans are highly vulnerable and susceptible to increased temperatures including extremely hot days and heatwaves, as well as days with significant rainfall, and water scarcity, as identified in Table 3-9. This vulnerability can lead to reduced yields, increased stress of agricultural workers, pest and rodent attacks, and crops spoilage, emphasizing the importance of effective harvesting, effective threshing and shelling, and using adequate drying and storage facilities and techniques.

An evaluation of the ten shortlisted flood resilience solutions (FL-RS) and their potential to mitigate the impacts of key climate hazards in the soybeans and maize value chains in Zambia 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 Zambia for maize value chain

Solutions	Climate hazards			Average rate
	Average temperatures, hot days over 35°C, and extreme heat and heatwaves	Days with rainfall > 20mm, large 1-day rains	Water scarcity	
Harvesting machinery	4	2	4	3,33
Mechanical multi-crop threshers and shellers	4	4	4	4.00
Tarpaulins and plastic sheets	5	2	4	3.67
Wooden and metal cribs	3	2	3	2,67
Metal and plastic silos	4	4	3	3.67
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	2	2.33

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

Solutions	Climate hazards			Average rate
	Average temperatures, hot days over 35°C, and extreme heat and heatwaves	Days with rainfall > 20mm	Water scarcity	
Harvesting machinery	4	2	4	3.33
Mechanical multi-crop threshers and shellers	4	4	4	4.00
Tarpaulins and plastic sheets	5	2	4	3.67
Wooden and metal cribs	2	2	3	2.33
Metal and plastic silos	4	5	3	4.00
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	2	2.00

Based on the 5-8 and

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

- Hermetic bags (4.00 points for both maize and soybeans)
- Mechanical multi-crop threshers and shellers (4.00 points for both maize and soybeans)
- Storage structures (4.00 points for both maize and soybeans)
- Metal and plastic silos (4.00 points for maize and 3.67 points for soybeans)
- Tarpaulins and plastic sheets (3.67 points for both maize and soybeans)
- Harvesting machinery (3.33 points for both maize and soybeans)
- Moisture meters (3.33 points for maize and 2.67 points for soybeans)
- Storage protectants and control agents (2.67 points for both maize and soybeans)

Baseline research findings, as detailed in subchapter 5.1 and confirmed by stakeholder engagements, have identified harvesting and subsequent threshing and shelling of soybeans and maize as critical loss factors (CLPs). To mitigate these losses, there is a need for the widespread adoption of mechanical multi-crop threshers and shellers within rural communities.

Such equipment can ensure proper threshing and shelling, reduce labour costs, and diminish both quantitative and qualitative physical crop losses.

Moreover, pest and rodent infestations represent another significant factor contributing to postharvest food losses in the maize and soybeans value chains. These infestations are primarily exacerbated by heat and inadequate storage facilities and techniques. Therefore, it is imperative to ensure the provision of durable, well-ventilated, and dry storage facilities. Effective storage solutions must encompass both on-farm storage and wholesale or communal storage options to safeguard the crops from such threats.

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 the smallholder farmers in Zambia, 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 Zambia are presented in the 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 the top 10 FL-RS in Zambia

Solutions	Estimated cost of the solution in Zambian Kwacha	Estimated cost of the solution in US dollars	Scoring
Harvesting machinery	45 000 – 100 000	1 600 – 3 600	1
Mechanical multi-crop threshers and shellers	2.500 – 31 800	90 – 1 250	2
Moisture meters	800 – 3 000	32 - 120	3
Metal and plastic silos	Est. 1 275 – 4 590	Est. 50 - 180	3
Wooden and metal cribs	Est. 640 – 2 040	Est. 25 - 80	3
Storage structures	n/a	n/a	3
Tarpaulins and plastic sheets	400 - 720	16 - 28	4
Transport packaging	500 – 1 500	20 - 58	4
Storage protectants and control agents	n/a	n/a	4
Hermetic bags	50 - 100	2 - 4	5

Source: (Agrimart, 2024)*;* (UBuy Zambia, 2024) (DesertCart Zambia, 2024)

Smallholder farmers generally require low-technology, familiar solutions that are relatively easy to acquire and maintain. Additionally, it is crucial to ensure that farmers possess the specific knowledge and capacity to utilize these solutions effectively. This will be supported by capacity-building and awareness-raising activities under Component 1 of the RE-GAIN Programme.

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 Zambia 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, there is a scarcity of quality low-technology solutions for harvesting, drying, and storing maize and soybeans coupled with insufficient knowledge regarding the optimal use of most FL-RS available on the market.

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

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

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

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

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 o points.

5.3.4 Final evaluation

Taking into consideration all the above-mentioned factors, and considering the major climate risks for Zambia specified in the previous chapters, the physical FL-RS for Zambia 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 Zambia

Solutions	Climate risks		Costs of the solutions	Best solutions in the local context	Final score
	Maize	Soybeans			
Harvesting machinery	3.33	3.33	1	2	9.66
Mechanical multi-crop threshers and shellers	4.00	4.00	2	4	14.00
Tarpaulins and plastic sheets	3.67	3.67	4	1	12.34
Wooden and metal cribs	2.67	2.33	3	1	9.00
Metal and plastic silos	3.67	4.00	3	4	14.67
Hermetic bags	4.00	4.00	5	2	15.00
Moisture meters	3.33	2.67	3	2	11.00
Storage structures	4.00	4.00	3	4	15.00
Storage protectants and control agents	2.67	2.67	4	0	9.34
Transport packaging	2.33	2.00	4	0	8.33

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 Zambia, 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 the

Table *5-13*.

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

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	Reduce labour input and cost, enabling farmers to manage larger areas. They are relatively simple to use, accessible, and time-efficient for small-scale farmers. Mobile threshers can be transported easily, and they speed up the shelling process before pests affect the crop.	Not suitable for handling large volumes quickly, and high fuel costs and pollution are concerns. Maintenance costs and the need for technical skills pose challenges, making them expensive for small-scale farmers.	Funding is a significant barrier, along with accessibility in rural areas, high fuel costs, and the expense for small-scale farmers. They are often not locally made.	Farmers prefer mobile threshers and shellers, as they can be moved within community/area and be used by several farmers
Tarpaulins and plastic sheets	Easy to use, effective, affordable, and simple to implement. They prevent water infiltration, are highly accessible and usable by regular farmers, and facilitate grain drying by exposing it to heat and sunlight, thus minimizing losses and maintaining quality.	The availability is limited, especially in rural areas. Overexposure to the sun can reduce product quality, and they have limited capacity, making them more suitable for small quantities. They are prone to pest infestations and contamination, and the process is time-consuming.	Scaling is challenging due to volume limitations, expense for farmers, and susceptibility to weather conditions, pests, and contamination.	Drying of maize and soybeans in Zambia could be improved by a combination of tarpaulins and plastic sheets with drying yards, or other constructions allowing to lift up the crop from the ground to avoid animal contamination
Metal and plastic silos	Silos provide optimal temperature and humidity for reducing grain losses. They are easy to construct by local artisans, effective, affordable, and suitable for household use with high storage capacity.	Despite their effectiveness, silos are expensive, with limited accessibility and susceptibility to theft. They can store only a limited quantity and are difficult to load.	High costs, lack of local knowledge and skills, and limited availability are major barriers, alongside the need for substantial investment.	Long-lasting and effective for pest control, maintaining grain quality. They are durable and easy to use, but require awareness and knowledge among farmers on the proper usage
Hermetic bags	Scalable, affordable, durable, and reusable. They provide an effective barrier against insects, withstand high temperatures, and offer quality assurance. Their familiarity with users encourages adoption.	At scale, they are not affordable and not 100% effective. They are prone to rodent damage and are not easily disposable. Handling large volumes is challenging, and improper grain drying can lead to rotting inside the bags.	Cost, limited availability, and difficulty in handling large volumes are significant barriers, along with the need for optimal grain drying.	Adoption is impeded by the presence of low-quality bags that are falsely marketed as high-quality hermetic bags. Furthermore, farmers frequently lack the essential knowledge regarding the quality and proper upkeep of these bags. Although smallholder farmers and individual households buy hermetic bags for on-farm use, the large quantity needed per household places a financial burden on these stakeholders.
Moisture meters	Enable farmers to determine moisture content before	However, they require specific knowledge and skills for use and have a	Farmer literacy, availability, cost, and affordability	Moisture meters, in addition to their relatively high costs, require technical

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
	marketing, ensuring safe storage. They are user-friendly, effective, and relatively easy to use, providing accurate measurements.	depth limit of about 20 cm.		knowledge for proper use, making them less favored by farmers
Storage structures	Most suitable for medium and large-scale farmers, providing good bulk storage and maintaining product quality. They are durable and have a high storage capacity, making them ideal for rural communities.	They are not affordable for smallholder farmers and are expensive. They are susceptible to pests, moisture, and rodents.	High investment costs, theft susceptibility, and pest exposure	The majority of consulted stakeholders have expressed a strong interest in community or government-owned storage facilities situated near their communities. This interest highlights a demand for accessible, secure storage solutions that can help farmers maximize their profits by timing the market effectively.
Storage protectants and control agents	These agents extend the produce life in storage, ensuring quality and affordability. They are locally available and effective, widely usable, and extend shelf life.	Chemical residues pose hazards to human health, affecting the smell and taste of produce and posing environmental risks.	Limited knowledge, improper handling, expense, and potential misuse of chemicals	Storage protectants are seen by many stakeholders as the cheapest solution to protect their crops. Farmers are generally aware about the possible negative impacts of overdose of those protectants on health

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. 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 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 are presented in Table 5-14:

Table 5-14 Prioritized physical FL-RS in Zambia

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

For the effective introduction and maintenance of communal storage, adequate facility management and maintenance, proper road infrastructure and sufficient transport availability will be crucial.

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

- ***Communal use by the target communities/farmer groups***: 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 Zambia to be deployed as basket of option as 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, and storage protectants and control agents.

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

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

Solution	Estimated reduction in PHL, % (Table 5-7)	Barriers for solution implementation	Proposed delivery mechanisms
Mechanical multi-crop threshers and shellers	10-30%	• High costs • Limited accessibility in rural areas • High fuel costs • Lack of locally produced machinery	• Improved access to solutions through a subsidy scheme • Capacity building (training of trainers) on managing and maintaining the machinery
Tarpaulins and Plastic Sheets	10-20%	• Limited scaling opportunities • Susceptibility to weather conditions, pests, and contamination	• Improved access to solutions through a subsidy scheme • Training and capacity building on the appropriate use of tarpaulins and plastic sheets
Metal and plastic silos	10-50%	• High costs/ need for substantial investment • Lack of local knowledge and skills in operation and maintenance • Limited availability	• Improved access to solutions through a subsidy scheme • Training and capacity building on the appropriate use of silos
Hermetic bags	20-30%	• High cost • Limited availability • Limited capacity for handling large volumes • Requires optimal grain drying	• Improved access to solutions through a subsidy scheme • Training and capacity building on the appropriate use of hermetic bags
Moisture meters	Up to 25%	• Farmers' literacy in using the meters • Availability	• Improved access to solutions through a subsidy scheme

Solution	Estimated reduction in PHL, % (Table 5-7)	Barriers for solution implementation	Proposed delivery mechanisms
		• Cost and affordability	• Training and capacity building on the appropriate use of moisture meters, and their maintenance
Storage structures	Up to 15%	• High investment costs • Theft susceptibility • Pest exposure	• Improved access to solutions through a subsidy scheme • Capacity building (training of trainers) on the best practices in using storage structures
Storage protectants and control agents	30-40%	• Lack of knowledge • Risks created by improper handling, potential misuse of chemicals	• Improved access to solutions through a subsidy scheme • Capacity building (training of trainers) on the best practices in using storage protectants and control agents

For the successful implementation of RE-GAIN programme, 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 in Zambia, 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

<table>
<tr><th>Identified risks, needs and barriers</th><th>Activity sets</th><th>Outputs</th></tr>
<tr><td rowspan="2">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</td><td>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</td><td>Output 1.1. Smallholder farmers supported to adopt FL-RS</td></tr>
<tr><td>Activity Set 2
• Facilitate market linkages between institutional markets & other buyers & smallholders, Support to structuring of value chains & coordination between market actors</td><td>Output 1.2. Improved market linkages between agri-value chain actors</td></tr>
</table>

Identified risks, needs and barriers	Activity sets	Outputs
• 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		
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
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

<u>Programme Advisory Group:</u>

AGRA will establish a Programme Advisory Group (PAG) made up of senior representatives from AGRA's Integrated Programme Management (IPM) unit[4] 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

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

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.

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[5] 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)

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

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
Zambia	• National Development Planning • Local Government • Health • Energy • Agriculture • Environment and Natural Resources • Communications • Minerals Development • Information and Broadcasting • Works and Supply • Home Affairs • Disaster Management and Mitigation • Gender

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.

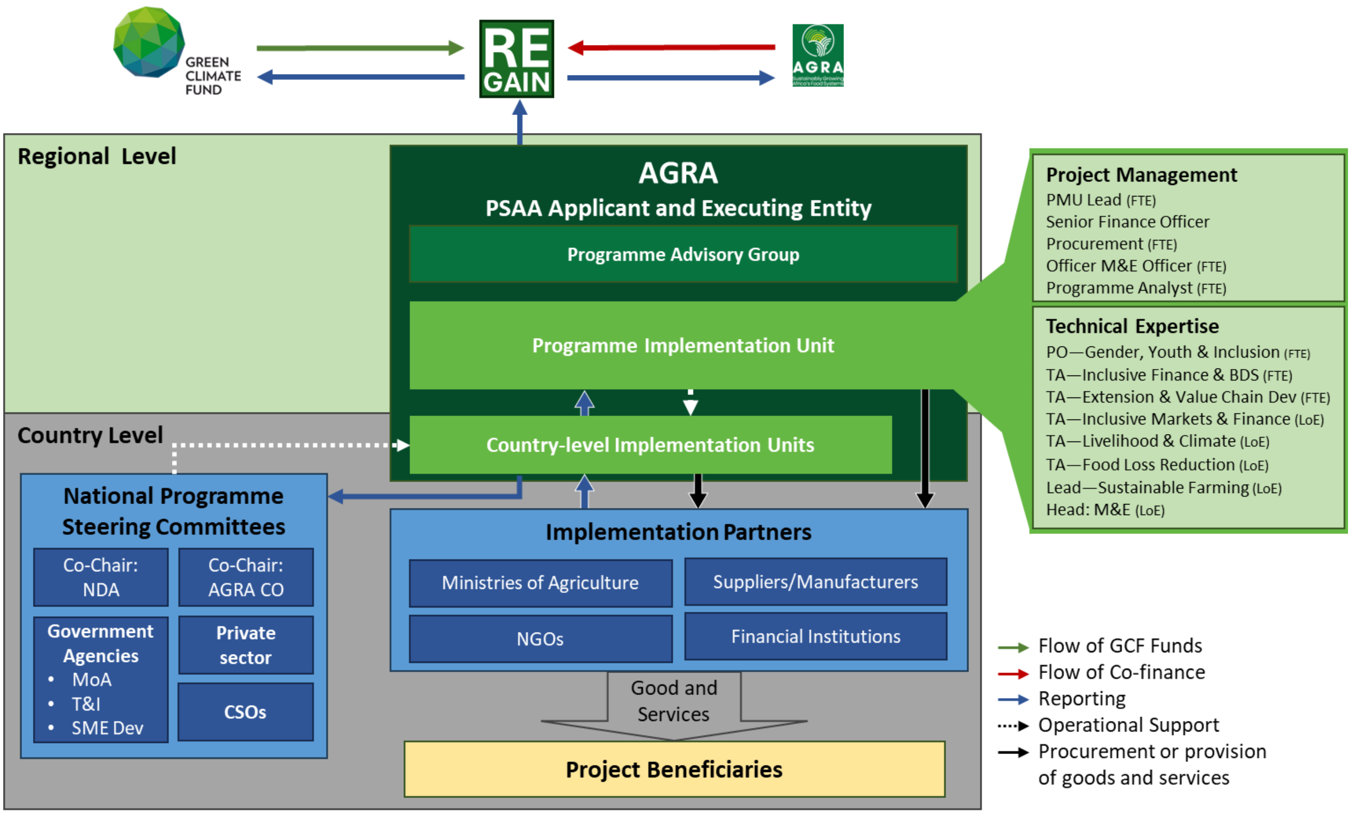


Figure 5-16 Implementation Arrangements for the RE-GAIN Programme

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 FOR THE PRIORITISED FL-RS

The demand and supply of agricultural machinery and other post-harvest food loss reduction technologies among smallholder farmers in Zambia 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 Zambia, 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 the specific FL-RS

Mechanical multi-crop threshers and shellers: in Zambia as well as in other African countries are in significant demand among farmers cultivating grains and legumes, to enhance productivity and reduce labor costs (AgriMart Africa, 2024) (FAO, 2020). Yet, supply is constrained by the high cost of equipment and limited local manufacturing (FAO, 2023).

Tarpaulins and plastic sheets are highly demanded particularly during the rainy season, to protect crops (Business Research Insights, 2024). While the supply chain is robust, affordability remains an issue, and high-quality, affordable products are often in short supply (Future Market Insights, 2023) (CCARDESA, 2023).

Hermetic bags have seen increased demand due to their effectiveness in protecting stored grains against pests and spoilage. Awareness and supply have improved, but they are still considered expensive and not always durable due to improper usage by some farmers, owing to knowledge and capacity gaps (Baributsa, 2020).

Metal and plastic silos are only in moderate demanded for their effectiveness in reducing post-harvest losses (Okori, 2022), due to their high costs and the need for proper installation and ongoing maintenance. In addition, the high production costs limit their supply (Mordor Intelligence, 2024). Adoption rates are low due to these cost barriers.

Moisture meters have low but growing demand as farmers become more aware of their use in preventing spoilage (Okori, 2022). Most devices are imported, and supply is constrained by high costs and limited distribution. There is a need for farmer training to promote proper usage.

Improved storage structures are in high demand to reduce post-harvest losses and store crops for longer in line better prices. However, the availability of modern storage solutions is low due to high costs (Wyman, 2018), making them inaccessible to smallholder farmers who often rely on less effective traditional structures.

Storage protectants and control agents are popular among smallholder farmers in Zambia, as they are generally affordable, and easily available. However, there is a lack of knowledge among them on the proper use and dosage of those chemicals, and limited availability of organic/natural alternatives with the same level of effectiveness on the national market.

The project aims to increase the demand for FL-RS through awareness raising and capacity building activities (Component 1). A key success factor for increasing demand is also through enhancing affordability, which includes easing access to finance and increasing the supply of affordable loans, so that farmers have funds to invest in the FL-RS. Component 2, output 2.2 will improve access to finance and examples of agricultural finance programmes are discussed in the next chapters.

6.2 MARKET OF SUPPLIERS AND MANUFACTURERS OF FL-RS

On the supply side of FL-RS, the agricultural sector depends often on expensive imports and relatively weak distribution networks which can severely restrict the availability of FL-RS in sufficient quantities at the right time/price. In Zambia, numerous manufacturers and/or importers of priority FL-RS operate regionally and locally. They are primarily located in big cities and collaborate closely with agricultural dealers as well as agricultural service providers. Markets are quite fragmented and consists of companies and service providers operating at different scales. Dealers and service providers engage directly with smallholder farmers, cooperatives and associations, selling the equipment and other solutions directly, or renting them out for certain periods.

The largest agricultural machinery companies such as Camco Equipment Ltd., Tractors Zambia, AFGRI Equipment Zambia (part of the AFGRI Group), BHBW Zambia Limited, Saro Agro, Agricon and Growmore Technology, provide agricultural machinery solutions such as **mechanical multi-crop threshers and shellers**, tractors and harvesting machinery. They distribute their products across the country through a network of dealers and agricultural machinery suppliers. See Annex for specific information about major companies, 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, **tarpaulins and plastic sheets** are commonly available in Zambia. They are mostly imported and sold by agricultural dealers directly to the farmers. Prices of those solutions might vary depending on the material, as well as country of origin (and the currency exchange rates).

Metal and plastic silos, and hermetic bags are among the most popular primary physical solutions for agricultural in Zambia. The five biggest manufacturers produce these solutions ensuring good availability in line with high demand. Leading producers in this sector are PPZ, Lamasat, Agrovet, and Afritank, which collectively have annual production capacity exceeding 500 000 bags and 5 000 silos. These companies, all primarily based in Lusaka, distribute their products through agrodealers and other third-party distributors nationwide. Despite fluctuations in demand and a 3% increase in exchange rates since 2020, market prices for both silos and hermetic bags have remained stable, indicating minimal impact from local currency variations. This stability suggests a well-balanced supply and demand dynamic in the market for silos and hermetic bags in Zambia.

Moisture meters in Zambia are primarily imported by companies such as NewGrow Co Zambia, 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. Frequently, moisture meters are imported to Zambia, and can also be bought online via agricultural marketplaces such as for example TradeKey or Ubuy Zambia.

Improved **storage structures**, such as for storage huts, or baskets, are most commonly built or assembled by the farmers directly at the household level from available construction materials. Bigger 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.

In Zambia, the local production of **crop protectants and control agents** is still relatively limited. However, a few companies like Cropserve Zambia and Greenbelt Fertilizers Ltd are active in this space, producing a range of pesticides, herbicides, and fungicides that are tailored to the local market conditions. Key importers and distributors of crop protectants and control agents in Zambia include Afrivet Zambia, Saro Agro Industrial Ltd, and Amiran Zambia. The distribution network for agrochemicals is reasonably well-developed, particularly in regions with intensive agricultural activity. However, access can be more challenging in remote areas, where infrastructure is less developed.

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

6.3.2 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.

6.3.3 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).

6.3.4 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.

6.3.5 Overview of key financing products that currently serve farmers in Zambia

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 Zambia. These initiatives encompass a variety of interventions and have had varying degrees of success and impact.

Among the government-led initiatives, implemented in collaboration with various partners, the most important in terms of postharvest loss reduction and relevant solutions are the following:

6.3.5.1 Sustainable Agriculture Financing Facility (SAFF)

The Sustainable Agriculture Financing Facility (SAFF), introduced by the Government of the Republic of Zambia, is an innovative initiative designed to empower Zambia's small-scale farmers by providing them with access to essential financial resources (Ministry of Agriculture of Zambia, 2024). Established as a low-cost loan facility with the goal of enhancing agricultural productivity and sustainability, SAFF aims to bridge the financing gap that smallholder farmers often face, enabling them to invest in better farming techniques, purchase necessary inputs, and ultimately increase their crop yields.

The Facility initially failed due to drought but has since been expanded to cover a broader value chain, including crop inputs, farm power, mechanization, aquaculture, and livestock breeding/feed lotting. This initiative has generated significant interest and demand for irrigation equipment and alternative sources of farm power, fostering a cultural shift among farmers towards loan repayment. By collaborating with financial institution, government bodies, and agricultural experts, SAFF offers a range of financing options that are accessible and affordable.

6.3.5.2 Farmer Input Support Programme (FISP)

The FISP, managed by the Government of the Republic of Zambia (GRZ) and the Ministry of Agriculture (MoA), provides essential agricultural inputs. The primary aim of FISP is to improve the accessibility of agricultural inputs for small-scale farmers at a reduced cost, thereby enhancing their productivity (Ministry of Agriculture of Zambia, 2024). Furthermore, the programme strives to bolster the involvement and competitiveness of the private sector in the supply and distribution of these inputs. FISP is now operational across all ten provinces and 116 districts of Zambia. The selection of beneficiaries, who are reviewed annually, follows criteria set by the Ministry of Agriculture. The implementation of FISP utilizes two main modalities, with a gradual transition planned to the latter to optimize efficiency: 1. Direct Input Supply (DIS): Under this approach, the government directly procures and pre-positions agricultural inputs across various districts. 2. Electronic Vouchers (eVoucher): This modality encourages private sector involvement in the redemption of inputs (Ministry of Agriculture of Zambia, 2024). The programme has demonstrated effectiveness in enhancing food security.

6.3.6 Citizen Economic Empowerment Commission (CEEC)

The CEEC is a statutory body in Zambia, established under the Citizen Economic Empowerment Act No. 9 of 2006. The primary goal of the CEEC is to foster broad-based and inclusive economic development by empowering Zambian citizens, particularly those who have been marginalized or disadvantaged. It was established by the Government of Zambia and the Ministry of Medium and Small-Scale Enterprises to provide capital access to beneficiaries, allowing them to choose their investment avenues (CEEC, 2024). One of its primary functions is the provision of funding (mechanisation loans, value chain development loans, postharvest asset loans, etc.) and grants. The CEEC offers financial support to eligible individuals and enterprises, enabling them to start or expand their business ventures. In addition to financial support, the CEEC focuses on capacity building. It provides training and capacity-building programmes designed to enhance the skills and capabilities of entrepreneurs and business owners. Despite its high level, the programme's criteria are not inclusive, resulting in few beneficiaries.

6.3.7 Constituency Development Fund (CDF)

Managed by the Government of Zambia and local governments, the CDF provides capital access aimed at community-driven projects to improve livelihoods (Presidential Delivery Unit, Office of the President of Zambia, 2024). However, the fund is susceptible to political influence which means it is not a reliable source of support.

Among the projects and initiatives implemented by the various donors in Zambia, the following ones are seen as the most impactful for Zambia:

6.3.8 Promotion of Village Savings Groups (2020 – 2022)

The World Food Programme (WFP) implemented this initiative with support of by various NGOs, including DAPP Zambia (WFP Africa, 2022). This intervention involved the use of physical solutions such as hermetic bags, silos, and shelling equipment.

Those target village groups were trained in a 'Savings for Change' method, implemented in Zambia by Self Help Africa and the WFP, that included business skills and financial management training. Promoting communal savings and enabling individual farmers to borrow from their group's fund at an agreed interest rate has generally been successful, providing farmers with easy access to finance, promoting savings, increased income, assets, production, and enhanced food security. The model relies on the principle that "no amount is too little to save" and encourages community members to pool resources to grow them at a steady rate while allowing members to draw from them to finance their ideas at a minimal interest rate. The model has proved to enhance women's access to finance through informal savings and credit options while also positively impacting their families and communities at large. Some of the notable benefits have been an increase in household assets, enhanced income diversity as well as empowering women to make financial decisions and contribute to the households' income (PMRC Zambia, 2020). However, additional resources are required to scale up these efforts effectively.

6.3.9 Global Innovation Challenge/ Maano – Virtual Farmers Market

Maano – Virtual Farmers Market" programme (WFP, 2024), launched in 2023, facilitated by the United Nations World Food Programme (WFP) and supported by local governments and private entities in Zambia, aims to enhance access to agricultural inputs and improve the availability of these inputs in remote areas through local agrodealers. It is part of a broader effort to increase resilience to climate crises and promote financial inclusion among small-scale farmers. The initiative also seeks to address gender disparities that exist in accessing resources and opportunities. With a strong focus on women farmers, the programme will work towards empowering them and ensuring their active participation in decision-making processes. The "Maano – Virtual Farmers Market" is an app-based e-commerce platform where farmers can advertise their surplus produce and connect with buyers, thereby improving market access and reducing post-harvest losses. The initiative also includes training on financial literacy, agricultural practices, and access to affordable credit and risk insurance, helping farmers manage climate-related risks and increase their productivity and income.

6.3.10 FL-RS Co-guarantee System, implemented by Vision Fund

Microfinance institutions, such as the Vision Fund, have introduced agriculture finance initiatives that provide inputs like seeds, fertilizers, and PICs bags (Purdue Improved Crop Storage (PICS) bags). This approach uses a co-guaranteed system within groups and offers direct financing to farmers who can provide collateral insurance. While access to finance has improved, the initiative has been limited by information dissemination.

Among the initiatives implemented in Zambia by the NGOs and various local players, the following ones are the most important ones, focusing on financing for FI-RS increased adoption:

6.3.11 Agleaseco's Asset Financing

A non-banking financial institution that offered access to finance to small-scale and emergent farmers - has been highly successful, with a positive impact and a default rate of less than 5% (AgriCoopNews, 2023). AgLeaseCo was funded by the German government through KfW and African Agriculture and Trade Investment Fund (AATIF). It did not require collateral, offered a fixed interest rate and fixed exchange rate, and allowed farmers to choose their own equipment. The repayment schedule was flexible, with options of 24, 36, 48, and 60 months, and compliant clients benefited from rebates or discounts. Despite this success, unstable equipment prices and a lack of awareness have hindered its full potential.

In summary, these initiatives have collectively contributed to reducing the costs of agricultural solutions in Zambia, although their scale is not enough to reach and solve across the different challenges currently faced by smallholder farmers in the country. However, they also highlight the need for improved information dissemination, enhanced financial literacy, and better collaboration among stakeholders to ensure broader adoption and sustained impact.

6.3.12 Suppliers of financial products and services

Local financial institutions such as AB Bank, Absa Bank Zambia Plc, Zambia National Commercial Bank (ZANACO) Plc., Atlas Mara Bank, Indo-Zambia Bank, National Savings and Credit Bank (NATSAVE Bank), Agora Microfinance, and Stanbic Bank play an active role in Zambia's agricultural sector. Apart from the commercial banks, the other main sources of agricultural credit in Zambia are parastatal institutions such as Agricultural Finance Company (AFC) and the Zambia Agricultural Development Bank (ZADB).

AGRA has secured letters of interest (LoI) with several financial institutions in the RE-GAIN countries 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 Zambia as potential partners:

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

Financial partner	Description
ZANACO	ZANACO is one of the largest and oldest financial institutions in Zambia, established in 1969. It offers a wide range of agricultural finance products aimed at supporting the agricultural sector, which is a crucial part of the Zambian economy. These products include loans for crop production, livestock, and aquaculture, as well as tailored financial solutions for both small-scale and commercial farmers. ZANACO also provides advisory services to help farmers improve their productivity and manage financial risks effectively.
ABSA	Formerly known as Barclays Bank Zambia, ABSA Bank Zambia provides comprehensive financial services, including specialized agricultural finance solutions. These services are designed to support various agricultural activities such as crop farming, and agribusiness ventures. ABSA's agricultural finance products include short-term and long-term loans, equipment financing, and working capital loans. The bank also offers value-added services like financial literacy training and market access support to help farmers maximize their potential.
Atlas Mara	Atlas Mara Bank offers a suite of agricultural finance products to support the diverse needs of farmers in Zambia. The bank's agricultural finance portfolio includes loans for crop production, livestock rearing, and agribusiness expansion. Atlas Mara emphasizes providing flexible and affordable financing options, along with technical support and advisory services to ensure farmers can achieve sustainable growth.
Indo Zambia	Indo Zambia Bank provides a range of financial products tailored to the agricultural sector, including loans for crop production, livestock, and agricultural infrastructure development. The bank focuses on supporting smallholder farmers and agribusinesses by offering competitive interest rates and flexible repayment terms. Indo Zambia Bank also collaborates with various stakeholders to provide technical assistance and capacity-building programmes, helping farmers adopt best practices and improve their yields.

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 (for 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.

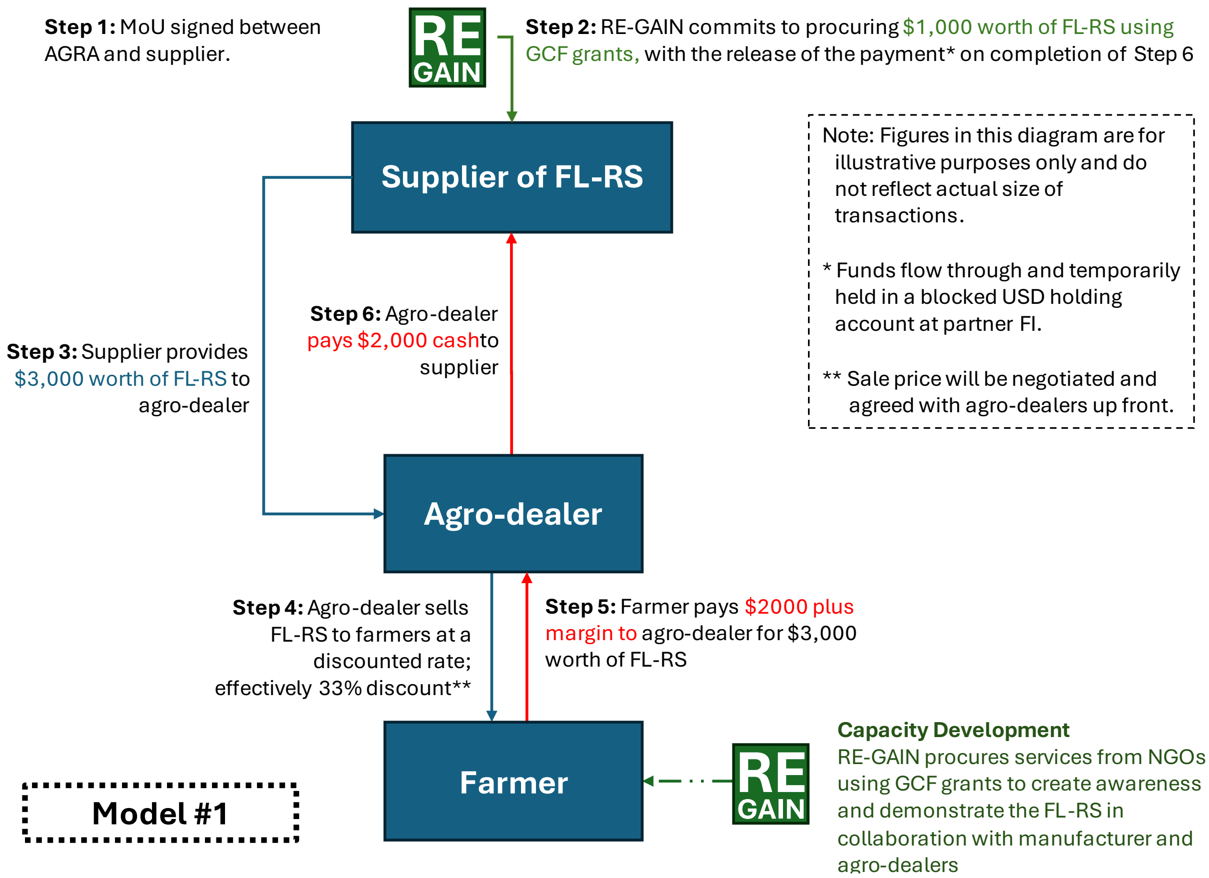


Figure 6-1 Model 1 for RE-GAIN Programme

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 and 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.

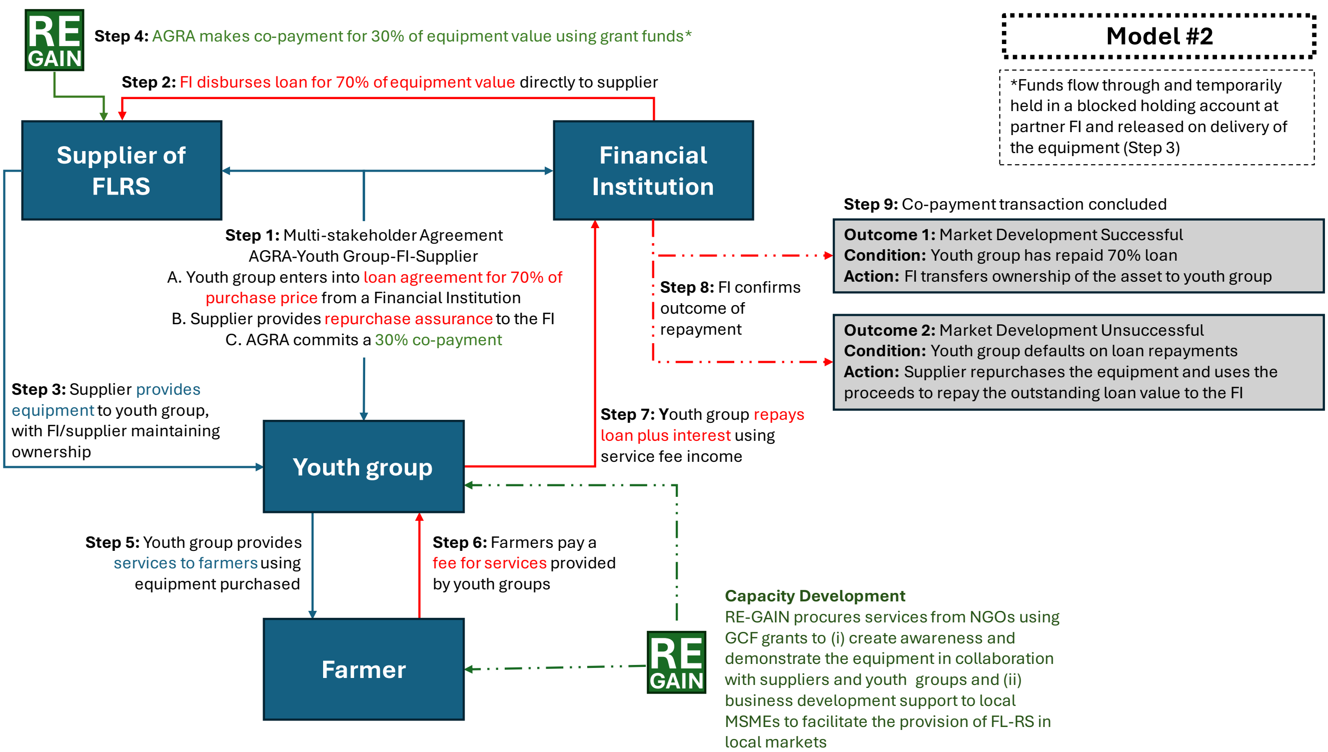


Figure 6-2, with detailed descriptions of each step in the following text. While RE-GAIN will facilitate the establishment of the entire process, its active involvement beyond Step 4, with ownership of Steps 5-9 transitioning to the three partners: youth groups, suppliers, and financial institutions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

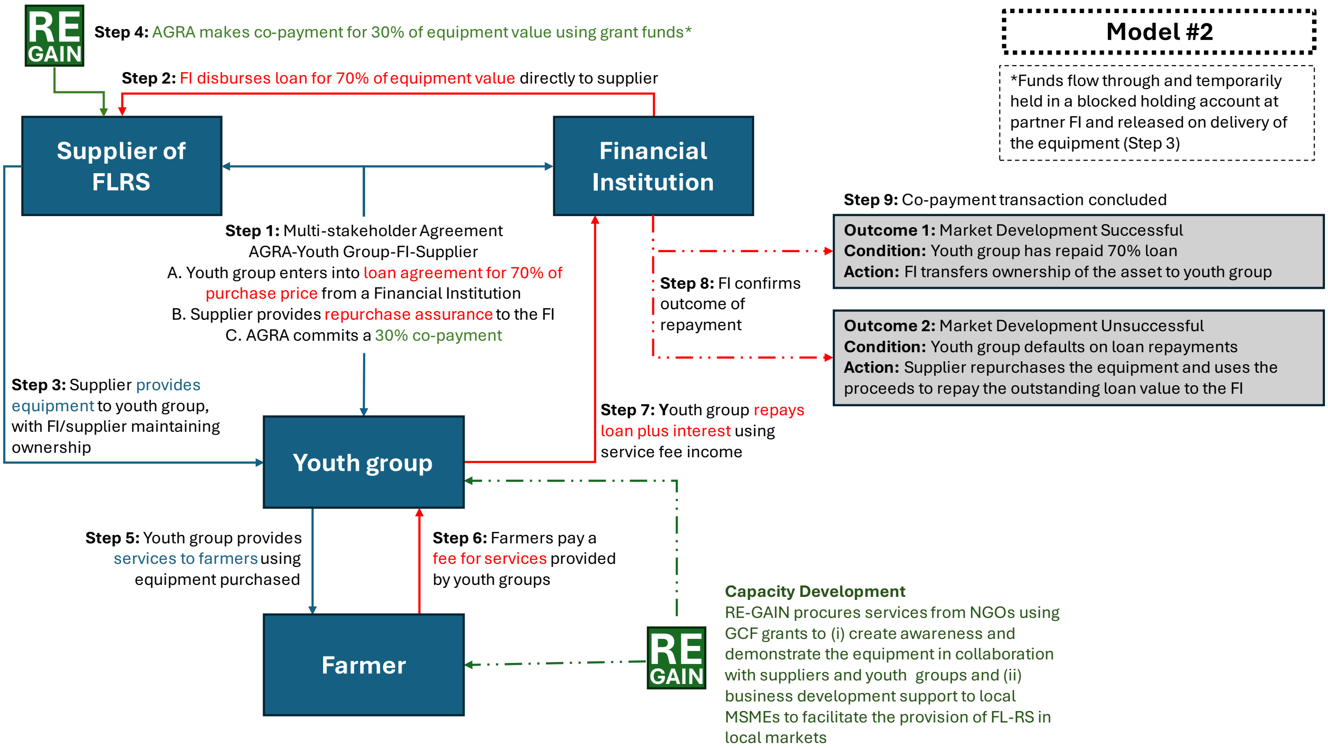


Figure 6-2 Model 2 for RE-GAIN programme

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, AGRA commits 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 (sub)bank 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 EXTENSIONS SERVICES: 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 Zambia 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 Zambia. The Ministry of Agriculture of Zambia will be a key partner, who is operating the extension services and several smallholder-oriented projects. UN and other international development organisations should be considered as potential partners in the awareness raising and capacity building activities in Zambia.

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

Organization	Description
Ministry of Agriculture of Zambia	https://www.agriculture.gov.zm Main partner in the programme and running the Agricultural Advisory Service in Zambia. The MoA cooperates with several training institutions, notably: Zambia Colleges of Agriculture, in Monze, Mpkia, and Mpongwe, which can help in the ToT The Ministry's E-Extension Service can be instrumental to reach many farmers in the awareness campaign as well as for disseminating technical information.
FAO Zambia	UN organization for food and agriculture that also promotes post-harvest food loss reduction; their vast experience, knowledge and information material will help the RE-GAIN programme to make a head-start.
Musika	Zambian NGO to empower smallholders. Its Value Chain VC programme: started in 2011 to benefit SHF (smallholder farmers)
National Association for Small Scale Farmers (NUZFAZ)	https://www.facebook.com/nusfazofficial/ info@nusfaz.org A member-based organization that champions the interests of small-scale farmers of Zambia.
Zambia National Farmers' Union	https://www.facebook.com/p/Zambia-National-Farmers-Union-100064473561004/ The Zambia National Farmers' Union (ZNFU) is one of the oldest associations in Zambia, a farmer-led organization that is engaged in promoting farming as a business.
Zambia Young Emerging Farmers Association - ZAYEFA	https://www.facebook.com/zayefa Created in 2016 and may be useful to mobilize young farmers.
One-Acre Fund Zambia	https://oneacrefund.org/ Focus is on tree planting, access to credit and carbon markets; their outreach may be useful to reach many smallholders
iDE Global Zambia	https://www.ideglobal.org/country/zambia iDE supports Zambia's small-scale farmers through agricultural advice, smart water management, and mobile technology solutions to increase market access and, ultimately, farm household incomes.

These organizations play a critical role in advancing Zambia'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 (hermetic bags or tarpaulins) preferably of the selected manufacturer or importer;
- Evidence of record keeping, including financial records. At 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;

6.5.1.5 Preferably engaging in the provision of solutions for smallholder farmers **MSMEs and Cooperatives (for activity 2.1.1 and activity 2.1.2)**

These partners will be selectedin 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 Zambia:

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 Zambian 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 Zambia 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 Zambia, with significant losses within the harvest and post-harvest stages for key crops in the country; soybeans and maize. 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 Zambia. 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 Zambia by addressing the key barriers identified during this phased study, as described in the image below:

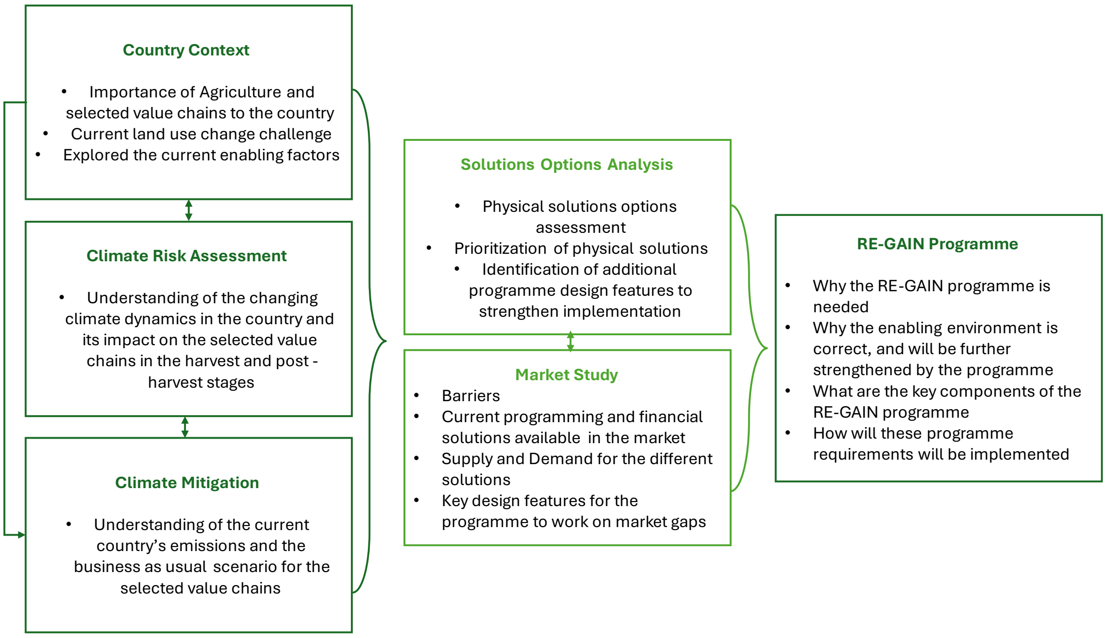


Figure 7-1 Content Summary of Feasibility Study for the RE-GAIN programme

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 soybeans and maize value chains within the Zambian 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. Zambia 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 Zambia 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 programmes 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 Zambia 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 Zambian 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 Zambia, and highlighted the lack of a unified initiative that can respond to these growing challenges and support Zambia's mitigation initiatives. RE-GAIN offers a solution by reducing food losses across the maize and soybean 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 Zambia. Over time, this programme will become self-sustaining, significantly improving the resilience and sustainability of the country's agricultural sector.

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