ANNEX 2

Malawi

Maize and Groundnuts
Version 4

2024

RE-GAIN: Scaling Solutions for Food Loss in Africa

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ACRONYMS

AGCOM	Agriculture Commercialisation
APHLIS	African Post-Harvest Loss Information System
BAU	Business as Usual
CA	Conservation Agriculture

CCAFS	Climate Change, Agriculture and Food Security
CCARDESA	Centre for Coordination of Agricultural Research & Development for Africa
CIAT	Centro Internacional de Agricultura Tropical (International Centre for Tropical Agriculture)
CLP	Critical Loss Points
CMIP	Coupled Model Intercomparison Project
COMESA	Common Market for Eastern and Southern Africa
CSA	Climate Smart Agriculture
DDPRR	Disaster Preparedness, Relief and Rehabilitation
FAO	Food and Agriculture Organisation of the United Nations
FL-RS	Food Loss Reduction Solutions
FSRP	Malawi Food Systems Resilience Program
GAFSP	Global Agriculture and Food Security Program
GCF	Green Climate Fund
GDP	Gross Domestic Product
GFDRR	Global Facility for Disaster Reduction and Recovery
GHG	Greenhouse Gas
GHGI	Greenhouse Gas Inventory
HDPE	High-density Polyethylene
HILDA+	Historic Land Dynamics Assessment
IDRC	International Development Research Centre
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
LUCF	Land-Use Change and Forestry
MGDS	Malawi Growth Development Strategy
MIP	Malawi 2063 First 10-Year Implementation Plan
MSME	Micro, Small, and Medium Enterprises
MwAPATA	Malawi Agriculture Policy Advancement and Transformation Agenda
NDA	National Designated Authority
NDC	Nationally Determined Contributions
PICS	Purdue Improved Crop Storage
QL	Qualitative
QN	Quantitative
REPP	Renewable Energy Performance Platform
SIL	Soybean Innovation Lab
SSA	Sub-Saharan Africa
SSP	Shared Socioeconomic Pathway
UNFCCC	United Nations Framework Convention on Climate Change
USDA	United States Department of Agriculture

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 Malawi, maize and groundnuts, two key crops, are significantly affected, **with post-harvest losses reaching up to 18.85% for maize** (APHLIS, n.d.) **and 32% for groundnuts** (FAO, 2018b). These losses impact food security and economic stability in Malawi. The country's extreme rainfall, droughts, and high temperatures exacerbate these food losses, **jeopardizing the livelihoods of over 80% of the population that relies on agriculture**, and posing a serious threat to the nation's overall food security and economic well-being (CIAT & World Bank, 2018).

Given the threat of climate change and the significance of agriculture to the economy, the management of post-harvest food losses within Malawi's agricultural activities and growing seasons, specifically maize and groundnut crop production, is necessary to ensure socio-economic stability. Agriculture is pivotal to Malawi's economy, supporting over 2 million rural smallholder farmers and contributing 40% to the GDP and employing approximately 80% of the workforce (CIAT & World Bank, 2018). Smallholder farmers, who manage 69% of the agricultural land, primarily cultivate maize and groundnuts, among other crops (CCARDESA, 2024). Maize is a staple food crop for Malawi, largely used for domestic consumption and food security. Groundnuts are important for Malawi, used for both domestic consumption and export, and are vital for economic stability and nutrition. The country's **agricultural activities are concentrated in various regions, with distinct growing seasons:** the warm wet season from October to April, the cool dry season from May to September (Republic of Malawi, 2021). Consideration of climate change impacts and associated mitigation and adaptation measures on crop production, processing, and subsequent food loss is therefore necessary to ensure socio-economic stability.

National policies and programmatic interventions that attempt to support climate change adaptation and mitigation along with post-harvest food losses are limited and require an intensified effort to support food security. Existing policies include Malawi's Climate Resilient Green Economy Strategy (2016-2020) and the National Adaptation Plan (NAP) (2020). These policies are largely targeted at enhancing agricultural productivity, promoting sustainable practices, and increasing climate resilience. Other programs have been initiated, such as the Scaling up the use of Modernized Climate Information and Early Warning Systems in Malawi and the Renewable Energy Performance Platform (REPP 2) under the Green Climate Fund (GCF). However, considering the significance of these sectors and the impacts of climate change on post-harvest food losses, Malawi's adaptation and mitigation efforts are inadequate, underscoring the need for deepened efforts towards the implementation of climate-resilient practices and technologies.

A deeper understanding of the climate risks associated with Malawi's agricultural sector is necessary to determine appropriate climate adaptation measures. Malawi faces significant climate risks, including rising temperatures, erratic rainfall, droughts, and extreme weather events such as floods and cyclones. These risks predominantly affect the southern and central regions, with areas like the Lower Shire Valley being particularly vulnerable (CIAT, World Bank, 2018). The impacts of these climate risks include increased crop spoilage, pest infestations, and mould growth, leading to reduced agricultural productivity and heightened food insecurity. Historically, Malawi has experienced a 0.9°C temperature increase, more frequent hot days and nights, and highly variable rainfall with prolonged dry spells during the rainy season. Climate change projections indicate a continued rise in temperatures, increased frequency of hot days over 35°C, and more intense rainfall events, exacerbating the country's vulnerability to floods and droughts (The World Bank, 2011). These projected trends underscore the urgent need for comprehensive climate adaptation and mitigation strategies in Malawi.

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 variable rainfall lead to reduced yields and increased post-harvest losses. This is evident with the rise in temperature and erratic rainfall patterns, particularly from 1960 to 2022. These climate trends have led to substantial yield reductions, with an observed total yield loss of 10.61% projected by 2050 (CCAFS, 2019). Projections indicate that maize yields will continue to decline under future climate scenarios. Additionally, post-harvest losses are exacerbated by increased pest infestations and mould growth. The losses will negatively affect food security and economic stability, as reduced yields will result in increased food insecurity and economic strain on smallholder farmers. Managing adaptation measures to stabilize maize yield and reduce post-harvest losses due to drought and variable rainfall is therefore critical for the value chain.

Groundnuts are similarly impacted by climate change, with higher temperatures and erratic rainfall patterns leading to decreased yields and increased food losses during the post-harvest process. For example, late onset of rains has resulted in higher costs to farmers from replanting seeds that do not germinate due to lack of moisture, impacting both crop production and post-harvest losses. Groundnut yields are projected to decrease by 5.84% by 2050 due to climate change impacts such as drought and extreme heat (CCAFS, 2019). The implication of these climate impacts on groundnuts includes increased spoilage and aflatoxin contamination. Therefore, climate adaptation measures for the growing and processing of groundnuts are vital to mitigate the negative effects of climate change on production.

Like adaptation, mitigation efforts are needed to minimize the negative effects of climate change on Malawi's agricultural sector. Malawi has a significant portion of its land, approximately 61%, suitable for agriculture, yet only 2 500 000 hectares are currently under cultivation, highlighting the potential for agricultural expansion. However, the country has faced severe deforestation, losing over 40% of its forest coverage between 1972 and 1990, and an additional 15% from 1990 to 2005 (Ngwira & Watanabe, 2019).. This deforestation is largely due to unsustainable land management practices, including the extensive use of trees for biomass, which fuels 89% of the country's energy supply (Heneine & Stephens, 2020).

Furthermore, Malawi's emissions trajectory is concerning, with agriculture and land use changes contributing to 54% of the country's greenhouse gas emissions (Republic of Malawi, 2021). Malawi's GHG inventory projects a substantial increase in emissions by 2030 under business-as-usual (BAU) scenarios. Emissions from agricultural sources, including methane from enteric fermentation and nitrous oxide from soil management, are projected to increase from 5.7 $MtCO_2e$ to 7.7 $MtCO_2e$ by 2030 (Republic of Malawi, 2021). In the land use change and forestry (LUCF) sector, there is predicated to be a 7% expansion in land used for crop production by 2032 (OECD & FAO, 2023a)

Of Malawi's emissions contributions, food losses account for a significant proportion of emissions, particularly in the post-harvest value chain. The emissions associated with food loss across the agricultural value chains considered by the RE-GAIN programme for Malawi could amount to 1 177 465 tCO2e from maize and 917 148 tCO2e from groundnuts, based on smallholder production values. Without intervention, emissions related to post-harvest losses on smallholder farms are expected to increase by between ~12% and ~21% across the target countries For Malawi, this could amount to 1,426,591 tCO2e for maize and 1,026,228 tCO2e for groundnuts by 2032. Therefore, it is crucial to minimize post-harvest food losses to reduce emissions and support climate change mitigation efforts.

The bulk of post-harvest losses contributing to agricultural emissions and requiring adaptation measures from field to market occur during storage, handling, and processing and are exacerbated by climate change. On-farm post-harvest losses in the maize value chain of 14.2% occur because of inadequate drying techniques, poor storage facilities, and pest infestations (APHLIS, n.d.). For groundnuts, on-farm post-harvest losses of 32% occur largely because of improper drying, aflatoxin contamination, and inadequate storage conditions (FAO, 2018b). Non-climate factors such as insufficient infrastructure, lack of access to modern storage technologies, and limited knowledge of post-harvest management practices also contribute to food losses in Malawi. Increased temperatures and erratic rainfall due to climate change worsen the already high post-harvest losses of maize and groundnuts because these conditions promote spoilage and pest proliferation, further threatening food security. Climate change exacerbates these issues, making mitigation and adaptation through post-harvest food loss management more salient.

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

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

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

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

This feasibility study showcases how climate change is likely to exacerbate food losses, and addressing post-harvest food losses in Malawi's maize and groundnuts 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 Malawi. 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 A. S., 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.

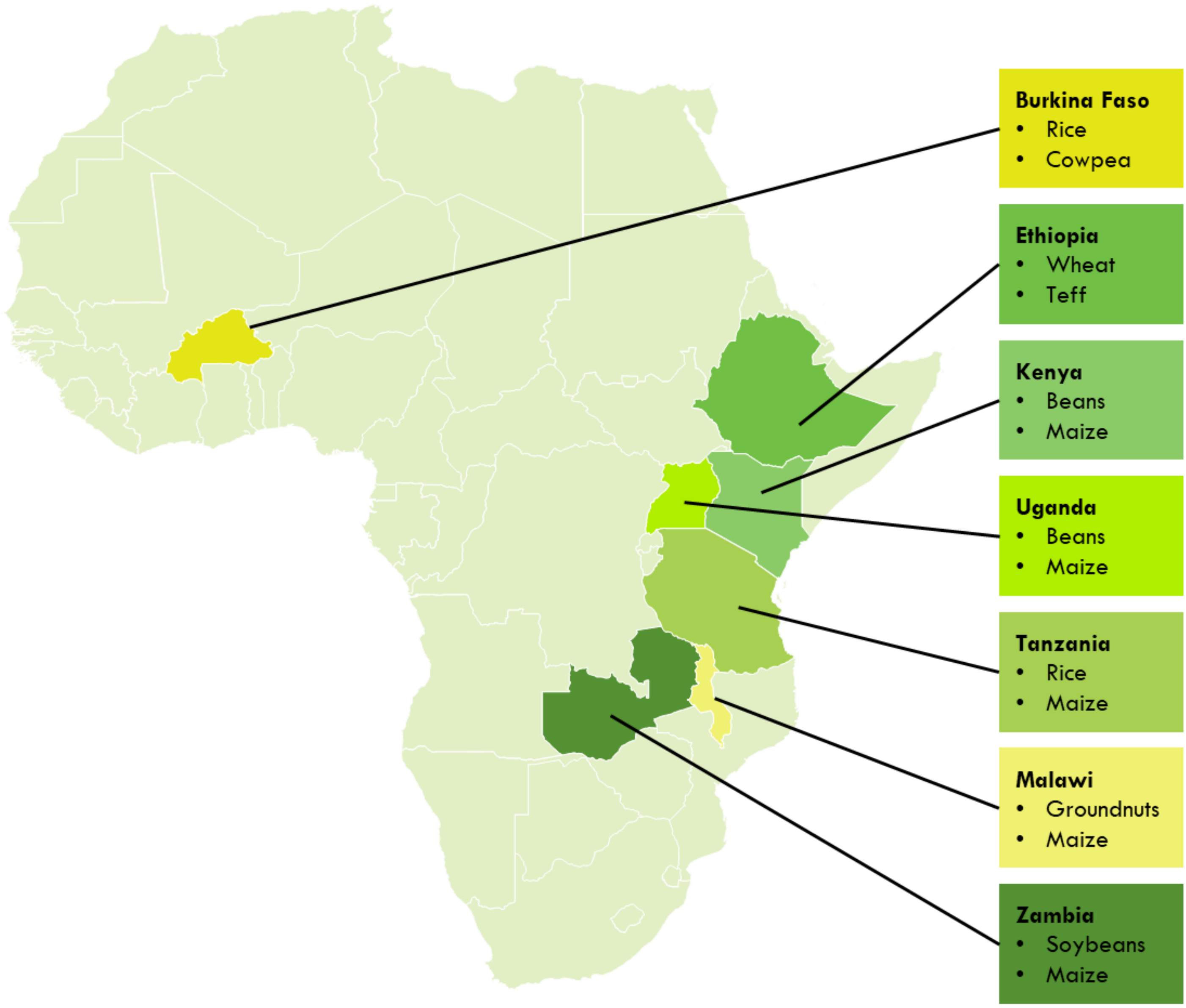


Figure 1-1 Focus Geographies for AGRA (2023-2027)

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

Malawi, situated in southern central Africa along the western part of the Great Rift Valley, spans a total area of 118 484 km², stretching approximately 900 km north to south and between 90 and 161 km East to West (COMESA, 2024). The country boasts abundant surface water resources, yet only 78,000 ha of its 400,000 ha of potentially irrigable land are currently irrigated, with smallholders cultivating just 30 000 ha, representing about 8% of the total irrigable area (CCARDESA, 2024). Of its 9.4 million hectares of agricultural land, approximately 32% are suitable for rainfed agriculture (CCARDESA, 2024).

Agriculture is pivotal to Malawi's economy, contributing 40% to Gross Domestic Product (GDP) (Republic of Malawi, 2021) **and employing about 80% of the population, with women accounting for 59% of agricultural labourers** (CIAT & World Bank, 2018). The sector sustains over 2 million rural smallholder farmers and is characterized by smallholder farms and large estates (CIAT & World Bank, 2018). Economic growth in Malawi is closely tied to agricultural GDP, which is highly dependent on climatic conditions. The country's agricultural production primarily centres on tobacco for export and maize for food (CIAT & World Bank, 2018).

Smallholder farmers in Malawi number approximately 3.1 million farming families, collectively managing 6.5 million hectares of land, constituting 69% of the country's total agricultural land under customary tenure (CCARDESA, 2024). These farmers operate on an average farm size of 0.7 hectares, with about 60% cultivating less than 1.0 hectare (CCARDESA, 2024). They play a crucial role in domestic food production, supplying around 80% of the food consumed in Malawi (CIAT & World Bank, 2018). However, their contribution to agricultural exports is limited to 20% (CIAT & World Bank, 2018), reflecting a dualistic agricultural economy where smallholder production accounts for nearly 70% of agricultural GDP. Major food crops include maize, rice, cassava, legumes, sweet potato, and Irish potato (CIAT & World Bank, 2018).

Malawi's smallholder farmers can be categorized into four groups. Firstly, commercially oriented farmers produce surplus crops beyond household consumption, comprising approximately 7% of the population with lower poverty rates (27%) and better access to irrigation and labour (CCARDESA, 2024). Secondly, subsistence-oriented rural households engage in farming alongside other livelihood activities, representing 64% of the population with poverty rates around 40% (CCARDESA, 2024). Thirdly, economically unproductive households, both rural and urban, face high poverty rates and comprise 13% of the population (CCARDESA, 2024). Lastly, urban households focus on non-agricultural economic activities, with relatively low poverty rates of 12%, making up 16% of the population (CCARDESA, 2024).

Women are integral to Malawi's agricultural sector, constituting 70% of full-time farmers, performing 70% of agricultural work, and producing over 80% of subsistence crops (CIAT & World Bank, 2018).

The country is divided into three agro-ecological zones based on soil types, altitude, rainfall variability, and temperature regimes: the Lower Shire valley, lakeshore plains and Upper Shire valley, and mid-altitude plateau, with occasional highlands (CIAT & World Bank, 2018). Malawi experiences two distinct seasons: a wet, warm season from October to April, and a dry, cool season from May to September (AGRA, 2018). Furthermore, it is subdivided into 18 livelihood zones reflecting varied agricultural production systems, geographic features, and market dynamics, each with distinct development needs and priorities (CIAT & World Bank, 2018).

Malawi's agricultural producers are predominantly small-scale, with emerging medium-scale farmers cultivating between 5 to 25 hectares of land (CIAT & World Bank, 2018). Large-scale producers, concentrated in regions like Thyolo, Mulanje, and

Nsanje districts, engage mainly in tobacco, tea, sugar, and macadamia production for export (CIAT & World Bank, 2018). Contract farming is common between large estates and smallholder farmers, particularly in tobacco and tea production (CIAT & World Bank, 2018).

More than 90% of agricultural production in Malawi relies on rain-fed methods, with only 4% of the total cultivated area benefiting from irrigation (AGRA, 2018). Women, who manage farms, face significant disadvantages in accessing irrigation technologies and financial resources (Murray, Gebremedhin, Brychkova, & Spillane, 2016). In some flood-prone regions like Salima, Karonga, and the lower Shire, approximately 6% of farmers practice recession agriculture, allowing for an additional harvest season in these areas.

Most smallholder farmers continue to utilize basic farming techniques such as hand-held hoes and watering cans, relying heavily on family labour (CIAT & World Bank, 2018). While fertilizer usage is higher than regional averages, there are disparities between farmers in urban and rural areas: 70% of urban farmers use fertilizers compared to only 55% of rural farmers (CIAT & World Bank, 2018). Differences also exist between male-headed and female-headed households, with 57% of male-headed households using fertilizers compared to 50% of female-headed households (CIAT & World Bank, 2018). Maize is a dominant crop that is cultivated by 95% of farmers (CIAT & World Bank, 2018).

With 80% of Malawi's population dependent on rain-fed agriculture, the sector—and consequently the economy—is highly vulnerable to climate change (CIAT & World Bank, 2018). Extreme weather events such as droughts, heavy rainfall, and floods have significantly impacted crop yields (CIAT & World Bank, 2018). Despite these challenges, the adoption of Climate Smart Agriculture (CSA) practices remains limited. For example, Conservation Agriculture (CA) covers only 1-2% of cultivated land, and irrigation covers just 4% of cultivated land (CIAT & World Bank, 2018). Key barriers to widespread CSA adoption by farmers include inadequate knowledge, limited access to financial resources, and land tenure insecurity, which disproportionately affect smallholder farmers (CIAT & World Bank, 2018).

2.2 TRENDS IN LAND USE CHANGE

Malawi, a landlocked country covering 118 484 km^2, with approximately 20% of its area covered by water, allocates 61% of its land area, or 5,738,000 ha, as suitable for agriculture, though only 2,500,000 ha are currently cultivated (CIAT & World Bank, 2018). Permanent meadows and pastures, forested areas, and other land cover types occupy around 20%, 34%, and 5% of the total land area, respectively (CIAT & World Bank, 2018).

Land ownership in Malawi is unevenly distributed, with wealthier individuals holding more land and enjoying better tenure security. Women account for only 32% of agricultural landholders (CIAT & World Bank, 2018). Large estates own 13% of the land, while smallholders possess 69% (CIAT & World Bank, 2018). Poor households, with per capita consumption below a dollar per day, typically manage holdings averaging 0.23 ha, contrasting with wealthier households averaging 0.42 ha (CIAT & World Bank, 2018).

The country's land tenure system categorizes land into customary (68%), public (20%), and private (12%) ownership (CIAT & World Bank, 2018). However, like many African nations, Malawi faces challenges in ensuring secure land tenure. Most smallholder farmers lack documented land rights, leading to inefficient resource use, low agricultural productivity, and increased land degradation risks (CIAT & World Bank, 2018). Inadequate land legislation further hampers productivity, especially on farms managed by women, as farmers hesitate to make long-term investments in insecure land (CIAT & World Bank, 2018).

Malawi has experienced significant deforestation, losing over 40% of its forest cover from 1972 to 1990, and a further 15% from 1990 to 2005 (Ngwira & Watanabe, 2019). Presently, only 3% of Malawi remains forested, largely due to unsustainable land management and agricultural practices (Heneine & Stephens, 2020). Shifting agricultural cultivation has been the primary driver of tree cover loss since 2001 (Heneine & Stephens, 2020).

Beyond meeting food demands, trees in Malawi serve as biomass, providing 89% of the country's energy supply (Heneine & Stephens, 2020). This extensive use of biomass contributes significantly to forest cover depletion, exacerbated by illegal logging and large-scale tree cutting to satisfy both local needs and international wood product demands.

2.3 NATIONAL AND SECTORAL POLICY LANDSCAPE

In Malawi, enhancing agricultural productivity and promoting commercialization remains a primary focus within long-term national strategies such as: Malawi 2063 Vision, the Malawi 2063 First 10-Year Implementation Plan (MIP-1 2021-2030), and the Malawi Growth Development Strategy (MGDS III 2017-2022).

***Malawi 2063 Vision* envisions transforming agriculture from subsistence to a commercial and diversified sector, positioning it as a pivotal driver of economic growth and food security** (National Planning Committee, 2020). This transformation will be achieved through promoting agribusinesses, adopting advanced technologies, and developing modern infrastructure such as irrigation systems, storage facilities, and processing units. The vision emphasizes the need for efficient market systems, access to finance, and capacity building for farmers. It also highlights the importance of climate-smart agriculture and sustainable resource management to enhance resilience to climate change. Key initiatives include expanding irrigation and fostering agro-processing industries. The goal is to create a competitive, resilient, and commercially viable agricultural sector that significantly contributes to national prosperity and improved livelihoods by 2063.

The *Malawi 2063 First 10-Year Implementation Plan* places a strong emphasis on agriculture as a cornerstone of economic development and poverty reduction (National Planning Commission, 2021). It outlines strategies to modernize the sector through technology adoption, improved infrastructure, and enhanced market access. The plan prioritizes sustainable farming practices to mitigate climate change impacts and ensure food security. It also focuses on promoting agribusiness and value addition to increase agricultural productivity and boost incomes for rural communities. Gender equality and youth empowerment in agriculture are key components, aiming to harness their potential for sectoral growth. Overall, the plan envisions a transformed agricultural landscape by 2063, driving inclusive economic growth and food sovereignty in Malawi.

The *Malawi Growth and Development Strategy (MGDS) III* outlines agriculture as pivotal to the country's economy, contributing significantly to GDP and employing a vast majority of the workforce (Government of Malawi, 2017). Emphasising the shift from subsistence to commercial farming, MGDS III focuses on diversification, value addition, and sustainable practices to enhance productivity and food security. Key priorities include infrastructure development, access to finance, climate resilience, and empowering women and youth in agriculture. The strategy aims to transform agriculture into a more resilient and productive sector, crucial for poverty reduction and economic growth in Malawi.

The *National Agriculture Policy (2016-2020)* acknowledges Malawi's vulnerability to climate change due to its reliance on rain-fed agriculture (Ministry of Agriculture and Food Security, 2010). Proposed adaptation measures include improving vulnerability assessments to provide early warnings on food security, enhancing food security, and establishing community-based storage systems for seeds and food. The policy also mandates environmental impact assessments for all agriculture projects and programs undertaken in the sector.

Furthermore, Malawi's updated ***Nationally Determined Contributions (NDC)*** of 2021 highlights that agriculture contributes the largest share of the country's total greenhouse gas emissions, accounting for 5.07 million tCO_2e or 54% of the total greenhouse gas (GHG) emissions in 2017 (Republic of Malawi, 2021).

The Malawi *National Adaptation Plan Framework* of 2020 aims to enhance community resilience to climate change through improved agricultural production, infrastructure development, and disaster risk management, ultimately ensuring food security nationwide (Ministry of Natural Resources, Energy and Mining Environmental Affairs Department, 2020)**.**

Among the other important national policies and frameworks relevant for the topic of food loss reduction, climate-smart solutions and GHG reductions, the following documents should be mentioned:

- National Environment Policy (2004),
- Implementation, Monitoring and Evaluation Strategy for National Climate Change Management Policy (2016),
- National Climate Change Management Policy (2016),
- Nationally Appropriate Mitigation Actions for Malawi (2015),
- Intended Nationally Determined Contribution (2015),
- National Climate Change Investment Plan (2013-2018),
- National Agricultural Investment Plan (2017/18-2022/23),
- Climate Change Learning Strategy (2013-2030).

2.4 LEGAL AND REGULATORY LANDSCAPE

No specific legal and regulatory documents have been identified in our initial analysis related to the topics discussed in this feasibility study.

2.5 GCF COUNTRY PROGRAMME DETAILS

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

In Malawi the GCF is implementing five projects which are summarized in

Table 2-1.

Table 2-1 To date, four country level readiness activities have been approved with a total approved readiness support budget of USD 4.1 million, of which USD 3.7 million is disbursed.

Table 2-1 - GCF Portfolio in Malawi

Project code	Focus	Geographical scope	Project title
FP222	Cross-cutting	Africa (Cameroon, Lesotho, Malawi, Nigeria, Zambia, Democratic Republic of the Congo, Madagascar, Niger, Sierra Leone)	Renewable Energy Performance Platform (REPP 2)
FP211	Cross-cutting	Africa (16 countries)	Hardest-to-Reach
FP177	Cross-cutting	Asia – Pacific, Latin America and the Caribbean, Africa, Eastern Europe (9 countries)	Cooling Facility
FP099	Mitigation	Asia – Pacific, Latin America and the Caribbean, Africa (19 countries)	Climate Investor One

FP002	Adaptation	Malawi	Scaling up the use of Modernized Climate information and Early Warning Systems in Malawi

Of specific relevance for the agriculture sector in Malawi is project ***FP002 "Scaling up the use of Modernized Climate information and Early Warning Systems in Malawi"***, with an estimated lifespan of 6 years (GCF, 2015). The project's efforts in Malawi are focused on safeguarding lives and sustaining livelihoods amid increasing climate-related disasters by enhancing early warning systems and strengthening community resilience. The country is experiencing more frequent and severe climate-related events such as floods, droughts, and extreme weather, which jeopardize lives, assets, and food security. The population's vulnerability to climate change is significant, with noticeable shifts in rainfall patterns, extended dry seasons, and shorter growing periods. With 85% of the population residing in rural areas, over half living in poverty, and many relying on smallholder agriculture, these changes pose serious challenges.

To address these issues, the project will expand the meteorological network by installing automatic weather stations, hydrological monitoring stations, and weather buoys on lakes. This infrastructure will enhance the ability to assess risks and predict impacts. Dissemination of weather information will be improved through mobile technology, information and communications technology, and radio, specifically targeting at-risk farming and fishing communities around Lake Malawi. Enhanced flood modelling for river systems will extend warning times from 6 hours or less to 24 to 48 hours. Engagement with the private sector, including telecommunications companies and small enterprises, will be increased. Additionally, the project will collaborate with affected communities to raise awareness and implement risk reduction measures in areas prone to flood disasters. Training and upgraded emergency services will bolster the emergency response capacities of local communities, district councils, and national agencies.

2.5.2 Other relevant projects (on food losses)

In the past decade, several initiatives have been implemented in Malawi to address food losses, focusing on improving food security and reducing waste.

Malawi Food Systems Resilience Program (funded by the World Bank) (GAFSP, 2024)

The project aims to boost the commercialization of both primary agricultural products and value-added goods, while also strengthening the resilience of the country's food systems. This will be a nationwide, multi-sector effort that integrates agriculture, water, land management, industry, trade, and other sectors. Interventions will be implemented across the entire country, expanding upon the achievements of AGCOM (1.0). This represents a shift from traditional, low-productivity approaches to a focus on commercial investments that generate income and employment opportunities. The project will foster the development of inclusive agri-food value chains by creating and fortifying farmer organizations and supporting productive alliances.

The Food Loss Research Program (IDRC, 2024)

The Food Loss Research Program is a collaboration between the Australian Centre for International Agricultural Research and the International Development Research Centre (IDRC). This initiative collaborates with partners in lower-income nations to address food loss through innovative locally tailored solutions. While initial projects have focused reducing losses in the mango and tomato supply chains in Sri Lanka and Pakistan, horticultural produce in the Pacific, and catfish in Vietnam and Laos, projects are planned in Malawi and Zambia to investigate food loss and its impacts on vulnerable urban communities. The primary objectives of these projects include:

- Analysing agricultural value chains within food systems at a provincial or local level across multiple countries where ACIAR and/or IDRC operate.
- Conducting foresight exercises extending to 2050 to predict changes in value chains based on trends, considering factors such as labour, technology, mechanization, climate change, urban and rural density, and nutritional needs.
- Engaging private agribusinesses along the value chain to document their food loss experiences and explore innovative models for long-term mitigation.
- Evaluating current local-scale interventions across the value chain.
- Assessing the factors that facilitate or hinder the transfer of intervention strategies from one location to another.

3 Climate Analysis - Adaptation

3.1 COUNTRY CLIMATE CHANGE BASELINE

Malawi is characterised by tropical continental wet and dry climate (Republic of Malawi, 2021)**, or – under the Köppen Geiger climate classification system – largely a Savannah climate** (Climate Data, n.d.). However, even within its relatively small geographic area, the country's climate displays a great deal of diversity due to topographic variability, including differential elevation and the cooling effects of Lake Malawi (The World Bank, 2011). The rainy season is from October through April, and the dry season is between May through September (Republic of Malawi, 2021). Malawi tends to be cool and dry from May to August, warm and dry from September to October, and warm and wet from November to April (Republic of Malawi, 2021).

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 (The World Bank, 2011):

- Temperature increases of approximately 0.9°C, with the most rapid increase in summer months (Dec–Feb);
- Increase in the number of hot days (+30 additional days a year) and hot nights (+41 additional nights a year);
- Highly variable year-to-year rainfall totals with no statistically significant trends;
- Increased length of dry spells during the rainy season;
- Increased spells of heavy rainfall, and increased intensity, frequency and magnitude of floods and droughts.

In recent decades the trend of increased average temperatures has been even more pronounced, as depicted in Figure 3-1, Figure , and Figure .

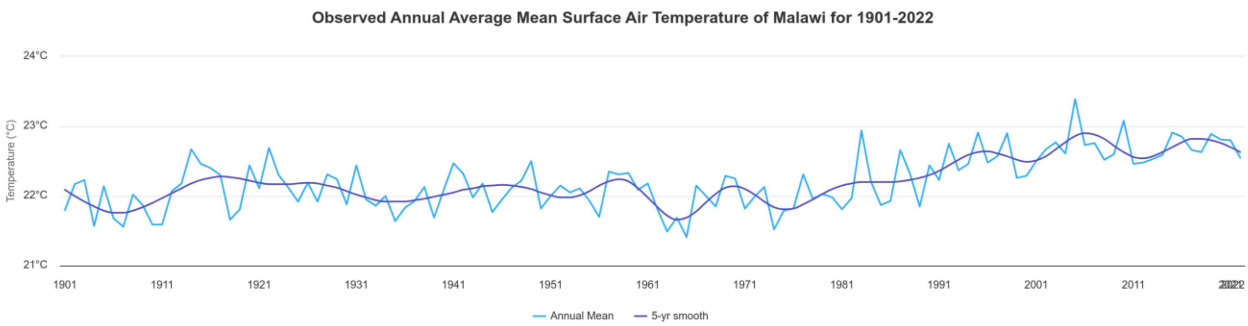


Figure 3-1 - Observed annual average mean surface air temperature of Malawi, 1901 - 2022 (World Bank, Climate Change Knowledge Portal)

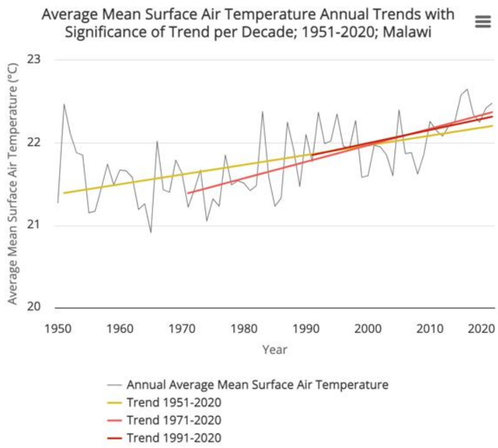


Figure 3-2 - Average mean surface air temperature annual trends with significance of trend per decade, 1951 - 2020, Malawi (World Bank, Climate Change Knowledge Portal)

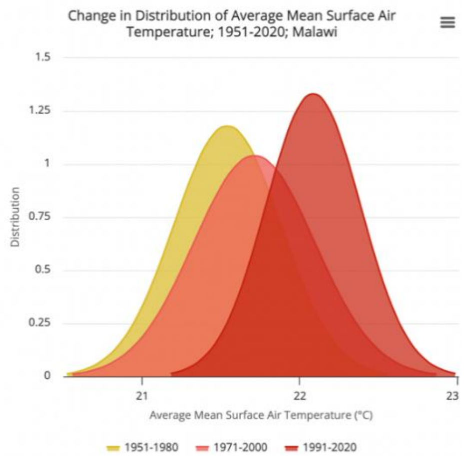


Figure 3-3 - Change in distribution of average mean surface air temperature, 1951-2020, Malawi (World Bank, Climate Change Knowledge Portal)

Observed mean annual rainfall trends for Malawi highlight an extremely high degree of inter-annual variability (The World Bank, 2011). Some studies suggest a marginal increasing trend over time (particularly in terms of increases in summer rainfall) (Finnish Red Cross and Red Crescent, 2021), while others infer a slightly decreasing trend (Republic of Malawi, 2021). According to the official submission of the Government of Malawi to the UNFCCC, the overall signal is a decrease in annual precipitation, albeit this is not a statistically significant trend, as illustrated in Figure .

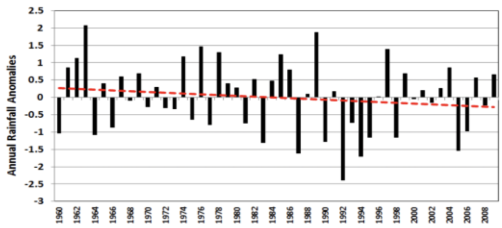


Figure 3-4 - Annual Rainfall anomalies over Malawi (1960-2009) (Republic of Malawi, Third National Communication to the UNFCCC, 2021)

Malawi has historically been highly prone to climate-related extreme weather events and disasters. The most recent Germanwatch climate risk index for cumulative disaster-related losses between 2000-2019 ranks Malawi as 62nd out of 180 countries (Eckstein, Künzel, & Schäfer, 2022). According to the European Union's INFORM climate risk index, Malawi's baseline risk level comprises an above-average vulnerability to climate-related hazards (5.6 out of 10), and a high lack of coping capacity (6.4 out of 10) (European Commission, n.d.).

Malawi's Department of Disaster Preparedness, Relief and Rehabilitation (DDPRR), in combination with global disaster databases, recorded over 270 disasters since 1991. According to the government, nearly 76% of these (205 out of 270) are climate-related, making climate change a major driver of disasters in Malawi (Republic of Malawi, 2021).

The number and severity of climate-related disasters in Malawi have increased in recent decades (The World Bank, 2022). According to the World Bank, between 2010 and 2022, Malawi experienced 16 major flooding events, a rainfall-related landslide, five storm-related disasters, and two severe droughts (The World Bank, 2022). Drought in 2015 left 6.5 million people food-insecure, including 3.5 million children (The World Bank, 2022). Tropical cyclones have also caused severe harm through flooding, including cyclone Idai in 2019, tropical storms Ana and Gombe in 2022, and cyclone Freddy in 2023.

3.2 AGRICULTURE SECTOR CLIMATE CHANGE BASELINE

Malawi's economy is heavily reliant on agriculture, with the sector contributing 40% of the country's GDP and 90% of its export earnings (Republic of Malawi, 2021). The sector is highly vulnerable to climate change, given the extremely high reliance on rainfed agriculture (accounting for over 90% of cultivation) (USAID, 2017), and the dominance of small-holder farmers (representing over 70% of the sector's labour force) (Republic of Malawi, 2021), who typically are under-resourced and under-capacitated to cope with shocks and stressors.

Maize is Malawi's key staple crop, grown by nearly 97% of farmers, and contributing to 60% of caloric intake (USAID, 2017). Maize cultivation accounts for 28% of the total harvested area in Malawi and is thus a principal driver of agricultural land use (The World Bank , 2019).

Maize is sensitive to changes in temperatures and rainfall. The Intergovernmental Panel on Climate Change's (IPCC) synthesis of global literature on 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 .

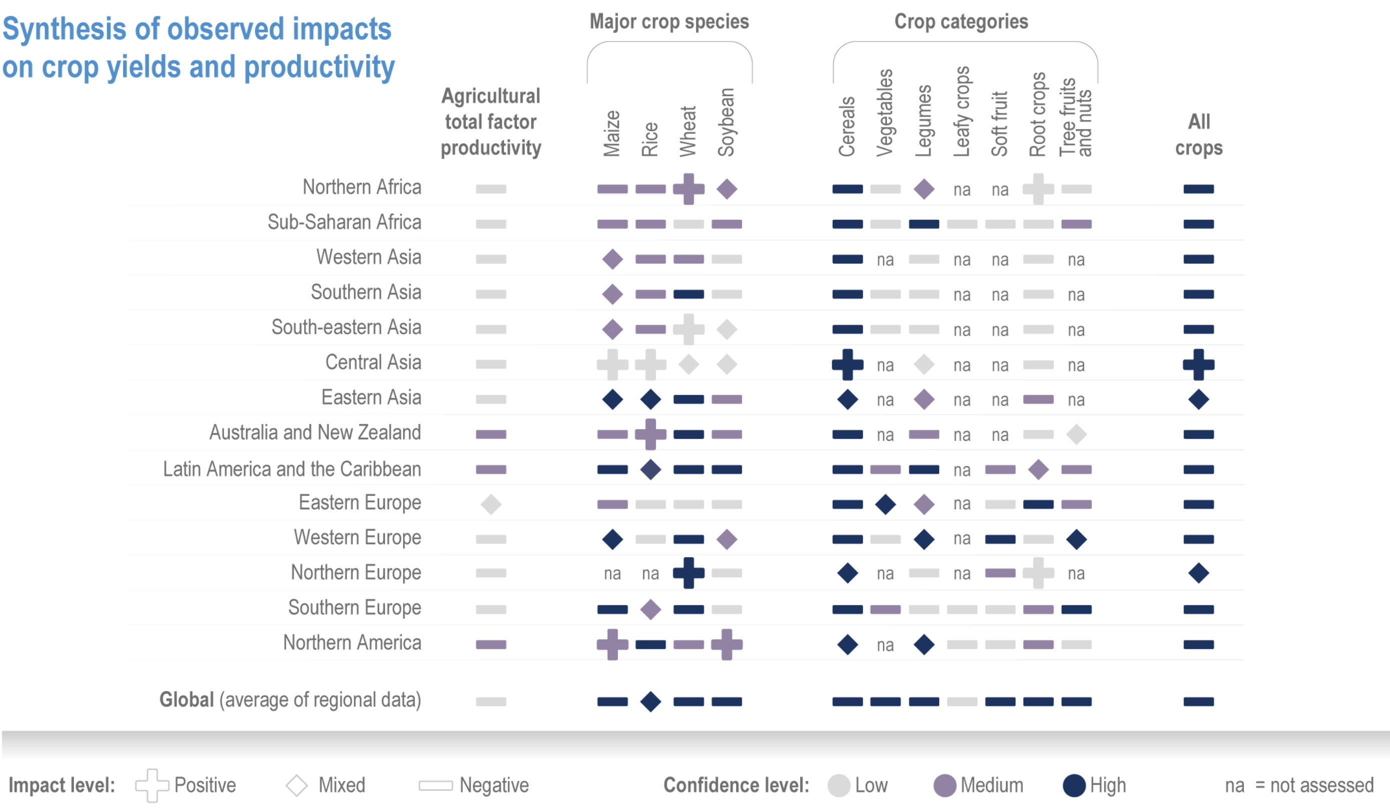


Figure 3-5 - Synthesis of literature on observed impacts of climate change on productivity by crop type and region (IPCC, 2021)

In recent decades, maize production in Malawi has suffered from frequent droughts (for instance, maize fell by 30% in 2015 due to drought), causing food shortages in the country periodically (USAID, 2017). Floods have also disrupted crop production and inflicted heavy losses, particularly in Malawi's southern region (USAID, 2017).

Groundnut is the second-largest crop in Malawi. Its cultivation accounts for approximately 6% of the total harvested area and is thus the second largest crop in terms of agricultural land use (after Maize) (The World Bank , 2019). Groundnut, a crucial export earner, is vulnerable to climate change. Higher temperatures and irregular rainfall are linked to decreased groundnut productivity, while intense rains pose the risk of increased incidence of aflatoxin (USAID, 2017).

A USAID climate change vulnerability assessment of Malawi found that for both maize and groundnuts, climate change – manifested particularly as high temperatures, variable rainfall, and increased moisture – was a hazard across several stages of the crop value chain (USAID, 2013).

Table 3-1 - Impacts of Climate Change on Crop Value Chains in Malawi: Maize and Groundnuts (USAID, Malawi Climate Change Vulnerability Assessment, 2013)

Link Crop	Field (e.g., planting, harvesting)	Storage and processing	Transport and Trading
Maize	No/erratic rains: Need to replant Excessive rains and water logging damage root system Drought/winds and frost damage or destroy crops Late rains affect pre-harvest drying in field Erratic rains push for pre-mature harvesting	Moisture and high temperatures trigger storage losses (esp. hybrids) due to increased pests/aflatoxin (result is shorter storage, granaries going out of style)	Flood events make farm to trading center roads impassable (result is reduced revenue)
Groundnuts	Erratic rains: Replanting Shorter rain periods reduce soil moisture: Short-duration varieties and/or use of gypsum to retain moisture; pes before planting, farmers ensure the whole ridge is fully covered by moisture. Short rainy season: Early-maturing varieties. Prolonged dry spells: More drought-resistant varieties.	Prolonged dry spells can be beneficial. Nuts can be stored longer under lower residual moisture levels. However, processors prefer high oil content varieties; but early maturing and drought resistant varieties tend to have lower oil content.	Late, heavy rains: May promote aflatoxin, reducing export market opportunities. Flood events make farm to trading center roads impassable (result is reduced revenue)

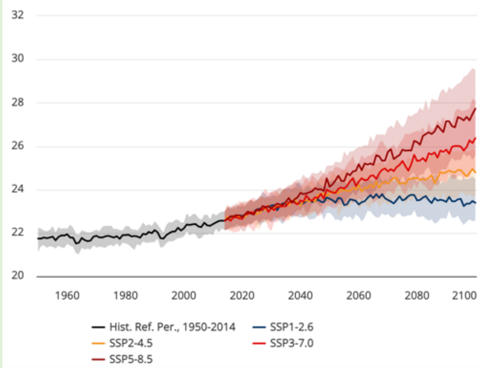
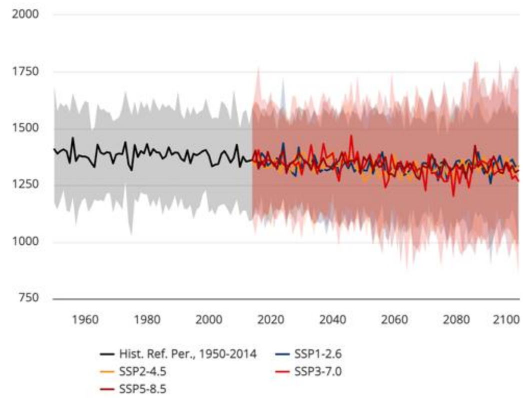
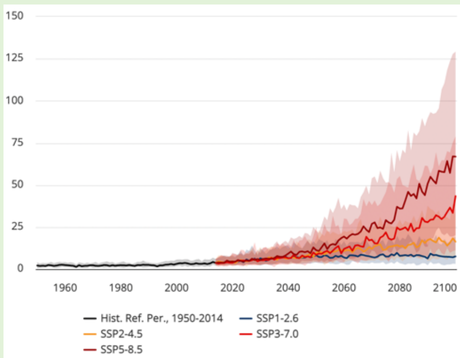
3.3 COUNTRY CLIMATE CHANGE FUTURE

For the analysis of future climate risks to the two crops of interest, Maize (corn) and Groundnuts (peanuts), our assessment looks at the 2040-time horizon (a timescale relevant to RE-GAIN's programmatic interventions). To identify future climate conditions that would (i) signal the major climate-driven threats that could impact post-harvest losses to the crops being considered, and (ii) inform the range and typologies of post-harvest reduction loss interventions to be selected, our analysis examines mean climate projections (using a multi-model ensemble, generated by the sixth Coupled Model Intercomparison Project, CMIP-6). Specifically, we have considered two modelled futures based on future shared socioeconomic pathway (SSP) scenarios:

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

We undertook a quantitative component of the climate risk assessment (see Annex Excel workbook "Malawi") and have integrated the findings from that assessment with qualitative excepts from relevant sources and literature, coupled with country-based crop experts, as presented below. Together, this mixed-methods approach offers a holistic view of climate change risk to the two chosen crops in Malawi, focused on post-harvest stages of the crop value chain.

Table 3-2: Principal Climatic Variables

Variable Name	In-Country Context Description	Additional information
Average Mean Surface Temperature	Across all future climate scenarios, **the average mean surface temperature in Malawi 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, we found that the projected rise in temperature from the historic baseline is high.	 *Figure 3-6 - Projected average mean surface temperature under multiple future scenarios (World Bank Climate Change Knowledge Portal: Malawi)*
Mean Precipitation	Across all future climate scenarios, mean **precipitation displays substantial variability** in climate projections, relative to the historic baseline (reference period 1950-2014). There appears to be a **slight downward trend**, however, the **decrease is not statistically significant**. In our assessment of projected change in mean precipitation in 2040, between the two future scenarios, we found that the estimated change in rainfall from the historic baseline was negligible (with a marginal decreasing signal).	 *Figure 3-7- Projected mean precipitation under multiple future scenarios (World Bank Climate Change Knowledge Portal: Malawi)*
Number of Hot Days over 35°C	Across all future climate scenarios, **the average number of hot days with temperatures rising over 35°C displays a rising trend**. The rise is more pronounced towards the end of the century, but even in 2040, the number of such days increases markedly from the historic baseline (reference period 1950-2014). Given that in the past there were only, on average 2 such days in the year, projections of potentially 6 (SSP 2-4.5) or even 9 (SSP 5-8.5) such days in 2040 is a notable percentage change. Thus, in our assessment, we found that the **estimated change in the number of hot days over 35°C is very high.**	 *Figure 3-8 - Projected change in number of hot days with temperature over 35°C, under multiple future scenarios (World Bank Climate Change Knowledge Portal: Malawi)*

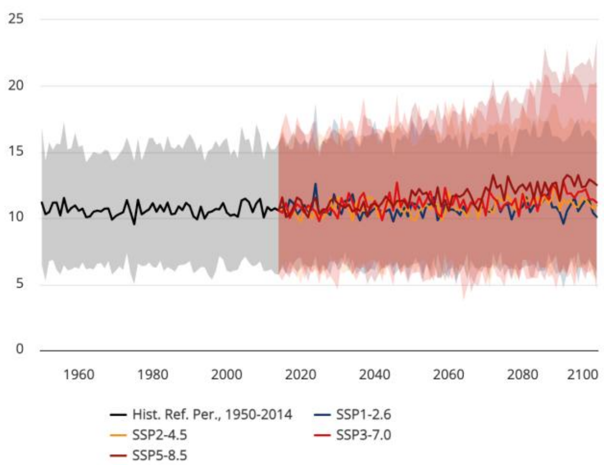
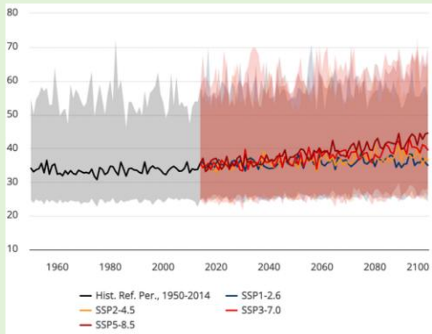
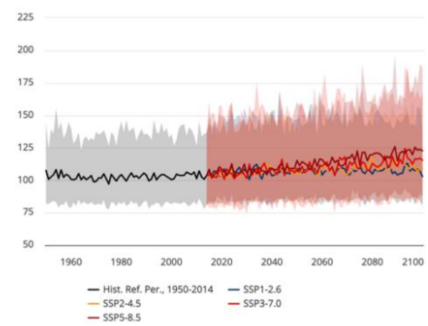
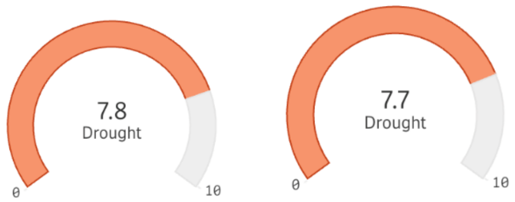
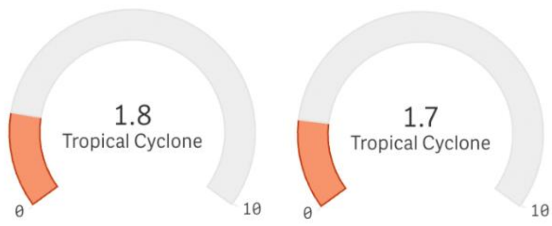
Variable Name	In-Country Context Description	Additional information
Number of days with rainfall > 20 mm	Across all future climate scenarios, the average **number of days with rainfall greater than 20mm displays a rising trend** (except SSP1-2.6). However, the trend does not demonstrate a particularly marked increase from the historic baseline (reference period 1950-2014). Given that in the past there were on average 10.64 such days in the year, projections of potentially ~11.15 (SSP 2-4.5) or ~11.11 (SSP 5-8.5) such days in 2040 are not a very notable percentage change. Thus, in our assessment, we found that the estimated change in the number of days with precipitation >20 mm is **moderate**.	 *Figure 3-9 - Projected change in number of days with rainfall >20 mm, under multiple future scenarios (World Bank Climate Change Knowledge Portal: Malawi)*
Average Largest 1-day Precipitation	Across all future climate scenarios, the average largest single-day (1-day) precipitation (a measure of heavy rainfall events) displays a high degree of variability in climate projections, relative to the historic baseline (reference period 1950-2014). Towards the end of the century, there is a slight apparent increasing signal, however, for the 2040 period, the increase is more modest. Nevertheless, in comparison to the baseline, in our assessment of projected **change in single-day rainfall, between the two future scenarios**, we found that the estimated change in rainfall was **high** (with an increasing signal).	 *Figure 3-10 - Projected change in average largest single-day precipitation, under multiple future scenarios (World Bank Climate Change Knowledge Portal: Malawi)*
Average Largest 5-day Precipitation	Across all future climate scenarios, the average largest five-day (5-day) precipitation (a measure of heavy rainfall events, which could trigger flooding) displays a high degree of variability in climate projections, relative to the historic baseline (reference period 1950-2014). The rainfall levels may increase towards the end of the century, however, for the 2040 period the increase is less stark. Nevertheless, compared to the baseline, **in our assessment of projected change in five-day rainfall, between the two future scenarios, we found that the estimated change in rainfall was high** (with an increasing signal).	 *Figure 3-11 - Projected change in average largest five-day precipitation, under multiple future scenarios (World Bank Climate Change Knowledge Portal: Malawi)*

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

Variable Name	In-Country Context Description	Additional Information
Water Scarcity (Linked to Drought Risk)	Malawi's future water scarcity risk in the face of climate change is regarded as **low.** This implies that "there is up to 1% 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 (7.7 out of 10) (European Commission, n.d.).	 *Figure 3-12 – Malawi'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	Malawi's future **extreme heat risk due to climate change** is regarded as **high**. This implies that "prolonged exposure to extreme heat, resulting in heat stress, is expected to occur at least once 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	Malawi's future **flood risk due to climate change** (and other factors) is regarded as **high**, particularly for river flooding (fluvial flooding, where river flows breach the banks) and urban flooding (pluvial flooding, or surface water flooding in built areas where rainfall exceeds infiltration capacity of the ground). "Potentially damaging and life-threatening river floods are expected to occur at least once in the next 10 years" (GFDRR, n.d.). According to the INFORM Climate Change Risk Index, Malawi's baseline risk of flooding (on a 0-10 scale) is 4.4 as of 2022. However, under the SSP2-4.5 scenario for mid-century (2050), this rises to 5.1, and under the SSP5-8.5 scenario, this rises to 5.2 for the same period (European Commission, n.d.).	 *Figure 3-13 - Malawi'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	Malawi'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.]	
Landslides	Malawi's **future landslide (or landslip) risk due to climate change** (and other factors) is regarded as **medium** (moderate). This indicates that the "area has rainfall patterns, terrain slope, geology, soil, land cover and (potentially) earthquakes that make localized landslides a known but nevertheless infrequent hazard phenomenon." (GFDRR, n.d.). [Note: the INFORM climate risk index does not provide data for landslides.]	

Cyclones	Malawi's **future tropical cyclone (or hurricane) risk** due to climate change (and other factors) is regarded as **medium** (moderate). This denotes that "there is a 10% chance of potentially damaging wind speeds in the area in the next 10 years." (GFDRR, n.d.) According to the INFORM Climate Change Risk Index, Malawi's baseline risk of cyclones (on a 0-10 scale) is 1.5 as of 2022. Under the SSP2-4.5 scenario for mid-century (2050), this rises to 1.8, and under the SSP5-8.5 scenario this shifts to 1.7 for the same period (European Commission, n.d.) However, despite these relatively modest risk scores, it should be noted that Malawi's risks from tropical cyclones are not principally from heavy wind speeds or cyclonic storm surges. In recent years the intense rainfall from cyclonic storms off the African coast has caused catastrophic flooding in Malawi, as was the case after cyclones Freddy and Idai.	 *Figure 3-14 - Malawi's future cyclone risk in 2050 under SSP2-4.5 and SSP5-8.5, on a scale of 10 (INFORM Climate Risk Index, 2024)*
Coastal Flooding	Not applicable (no coastal region)	
Sea Level Rise	Not applicable (inland country without an oceanic coastline).	

3.4 THE FUTURE OF CROP PRODUCTION IN LIGHT OF CLIMATE CHANGE

3.4.1 Maize

One of the chief climate impacts on maize (corn) production in Malawi is a projection of seasonal shifts in rainfall, i.e. potentially late onset of rains. A USAID study suggests that with such a delay in rainfall, maize farmers will incur additional costs due to the need for replanting, along with the need for additional weeding, ridging, drying/shelling, and pesticides (in storage) (USAID, 2013). Furthermore, **longer dry spells during the rainy season could raise the cost of production almost as much as late-onset**, principally because if extremely long dry periods occur early in the growing season, this could also require a complete re-planting of the seeds, thereby doubling the cost of seeds and ridging (USAID, 2013).

Several studies indicate that climate change impacts on maize production in Malawi (where it is the most dominant crop) will result in reduced yields, i.e., will depress production. One analysis, for instance, estimates that rainfed maize production in the Lilongwe District, the largest maize-growing district in Malawi, may decrease up to 14% by mid-century due to climate change (Msowoya, Madani, Davtalab, Mirchi, & Lund, 2016). Another study estimates that climate change is likely to reduce the yields of maize in Malawi by 10.61% by 2050 (CCAFS, 2019).

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

3.4.2 Groundnuts

Rainfall variability, and shifts in rainfall seasonality and timing, could be a risk to groundnut production in Malawi under future climate change conditions. According to a study by USAID, late onset of rains would result in higher costs to farmers, from

having to replant (approximately half of) the seeds that do not germinate due to lack of moisture (USAID, 2013). The study also suggests that additional work on the tier ridges would be another significant cost component (USAID, 2013).

One investigation notes that climate change poses challenges to the productivity of groundnuts in Malawi. The negative effect is due to erratic rainfall and dry spells, especially during critical periods of growth and development. Groundnut cropping in Malawi is entirely rain-fed and thus is highly sensitive to climatic stressors such as dry spells (Chinsinga & Matita, 2021).

Another study estimates that climate change is likely to reduce the yields of groundnuts in Malawi by 5.84% by 2050 (CCAFS, 2019). According to this analysis, even as yields of groundnuts decrease, the areas under groundnut production in Malawi are likely to increase by 7.6% by 2050 (i.e., more land will be used for groundnut cropping), but this may be irrespective of climate change (CCAFS, 2019).

Note to readers: Published literature is scarce on the climate impacts on post-harvest stages of the groundnut value chain (in Malawi 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 Malawi indicates that the most significant **hazards** are **temperature (increases in average temperature, as well as increases in the number of extremely hot days where temperatures breach the 35°C threshold), heavy or intense precipitation (extreme volumes of rainfall in a single day or five-day period), flooding (pluvial and fluvial), and wildfires.** To a slightly lesser degree, landslides and cyclones also pose a threat.

Malawian stakeholders at the national and local levels affirmed that for the maize value chain, climate hazards that pose the most substantial risk at harvest and during the post-harvest stages are **heavy or intense rainfall (excessive and erratic), flooding, and high temperatures (extreme heat). Stakeholders also expressed concern about the increased incidence of pests and crop diseases whose prevalence is affected by climatic factors (temperature and humidity), especially fungal diseases like mould that leads to aflatoxin contamination.**

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

Table 3-4 - Top three climate change hazards identified for Malawi'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
Lilongwe	Excessive and erratic rainfall (including variable or heavy rain); Flooding. High temperatures (extreme heat)	Excessive and erratic rainfall (including variable or heavy rain); Flooding. High temperatures (extreme heat)	Excessive and erratic rainfall (including variable or heavy rain); Flooding. High temperatures (extreme heat)
Nathenje	Excessive and erratic rainfall (including variable or heavy rain); Flooding. High temperatures (extreme heat)	Excessive and erratic rainfall (including variable or heavy rain); Flooding. High temperatures (extreme heat)	Excessive and erratic rainfall (including variable or heavy rain); Flooding. High temperatures (extreme heat)

A range of factors create **vulnerability** in the Maize value chain, including a very high percentage of rural population (dependent on agriculture), very low levels of irrigation and a high reliance on rainfed agriculture, and high levels of poverty and unemployment (noting that some of these vulnerability factors apply to the value chain and the agricultural sector as a whole, and are not specific to post-harvest stages of the maize value chain in particular).

Stakeholders in Lilongwe and Nathenje added further granularity and insights to the understanding of vulnerability in the maize value chain, indicating that principal drivers of vulnerability in Malawi's maize value chain – at harvest and during post-harvest stages – are: **a lack of access to appropriate technology and equipment and facilities (such as adequate drying and storage facilities and other post-harvest infrastructure); lack of necessary knowledge and skills (including warehouse management); the reliance on traditional and manual techniques (rather than mechanised practices, such as for harvesting and threshing); and the lack of or low levels of crop insurance.**

Specifically, stakeholders in Lilongwe and Nathenje identified the three most important vulnerability factors that make the maize value chain susceptible to climate change risks, corresponding to RE-GAIN's three value chain stages, as shown in Table 3-5.

Table 3-5- Top three climate change vulnerability factors identified for Malawi'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
Lilongwe	Lack of/limited access to technology, equipment, facilities, infrastructure (e.g., for harvesting) Lack of/limited access to knowledge and skills (e.g., storage and pest control) Reliance on traditional, manual techniques (over mechanization).	Lack of/limited access to technology, equipment, facilities, infrastructure (e.g., for threshing and drying) Lack of/limited access to knowledge and skills (e.g., storage) Reliance on traditional, manual techniques (over mechanization).	Lack of/limited access to technology, equipment, facilities, infrastructure (e.g., for transport) Lack of/limited access to knowledge and skills (e.g., storage) Limited access to more reliable or well-equipped markets.
Nathenje	Lack of/limited access to technology, equipment, facilities, infrastructure (e.g., for harvesting) Lack of/limited access to knowledge and skills (e.g., storage and pest control) Reliance on traditional, manual techniques (over mechanization).	Lack of/limited access to technology, equipment, facilities, infrastructure (e.g., for threshing and drying) Lack of/limited access to knowledge and skills (e.g., storage) Reliance on traditional, manual techniques (over mechanization).	Lack of/limited access to technology, equipment, facilities, infrastructure (e.g., for transport) Lack of/limited access to knowledge and skills (e.g., storage) High costs and limited affordability of appropriate tools and methods for storage and transport.

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 that Malawi is already facing.

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

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

Quantitatively, in our comparative climate change risk assessment, quantitatively the risk level of the maize value chain in Malawi scored: 73.313 out of 125, putting it at rank **1** of the 14 crop value chains similarly assessed.

Table 3-6 - Comparative scoring of climate change risk for crop value chains in RE-GAIN countries

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

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

The impacts of temperature and moisture, as well as extreme weather events on 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 Malawi 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 17% of the maize harvest in Malawi was lost as dry-weight, post-harvest loss in 2022, and over a ten-year period the total post-harvest dry-weight loss in Malawi for maize (average of 2013-2022) was 18.85%** (APHLIS, n.d.). APHLIS defines the post-harvest value-chain stages as: harvesting/field drying; further drying; threshing and shelling; winnowing; transport from field; household level storage; transport to market; and market storage (APHLIS, n.d.). Based on decadal data from 2013 through 2022, of these post-harvest value-chain stages, the three stages where the largest volume of maize losses occurred in Malawi (in decreasing order) are:

1. **Household-level storage** (by far the stage of greatest losses) – an average annual loss of 7.65% of the crop
2. **Harvesting and field drying** – an average annual loss of 6.3% of the crop
3. **Further drying** – an average annual loss of 4% of the crop.

Together, these three stages (which account of nearly 18% of all maize lost in Malawi) represent **19.225%** of the total (annual average) *post-harvest losses* in the maize value chain in Malawi. In each of these three stages, **climatic factors are highly**

relevant, given how temperature, moisture, 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 Malawi, ***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, and harvesting and field drying, it is fair to surmise that the areas in Malawi where maize is farmed are the dominant geographical locations for these losses, at these stages. Based on the map of maize growing areas in Malawi (below) (United States Department of Agriculture (USDA), n.d.), the districts of **Kasungu** (accounting for 29% of maize production in 2022-2023) and **Lilongwe** (23% in 2022-2023) may be prioritised for climate-responsive, risk-reduction interventions.

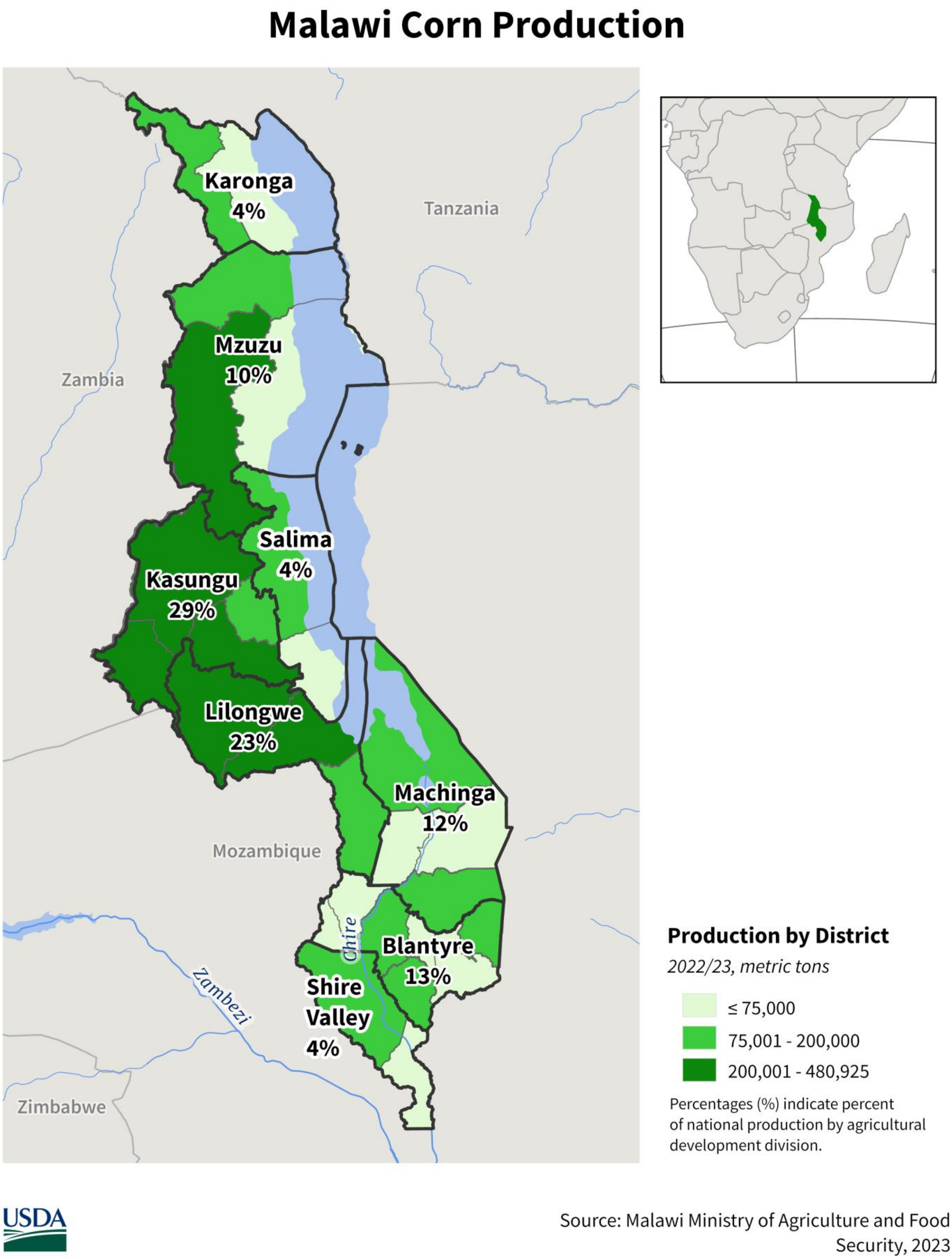


Figure 3-15 - Malawi: Maize Production by District, 2022-2023 (USDA, 2023)

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

- Kasungu,
- Lilongwe,
- Mzuzu,
- Salima.

3.5.2 Groundnuts

Our analysis of climate change risks to the groundnut value chain in Malawi indicates that the most significant **hazards** are **temperature (increases in average temperature, as well as increases in the number of extremely hot days where temperatures breach the 35°C threshold), heavy or intense precipitation (extreme volumes of rainfall in a single day or five-day period), flooding (pluvial and fluvial), and wildfires.** To a slightly lesser degree, landslides and cyclones also pose a threat.

Malawian stakeholders at the national and local levels affirmed that for the groundnut value chain, climate hazards that pose the most substantial risk at harvest and during the post-harvest stages are **dry spells or droughts, heavy or intense rainfall (excessive and erratic), flooding, and high temperatures (extreme heat). Stakeholders also expressed concern humidity levels, because moisture is a major threat to groundnuts.**

Specifically, stakeholders in Lilongwe and Nathenje 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 Malawi's groundnut 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
Lilongwe	Drought / dry spells. Flooding as a result of excessive and heavy rainfall events. High temperatures (extreme heat).	Drought / dry spells. Flooding as a result of excessive and heavy rainfall events; High temperatures (extreme heat).	Drought / dry spells. Flooding as a result of excessive and heavy rainfall events. High temperatures (extreme heat).
Nathenje	Drought / dry spells. Flooding as a result of excessive and heavy rainfall events. High temperatures (extreme heat).	Drought / dry spells. Flooding as a result of excessive and heavy rainfall events. High temperatures (extreme heat).	Drought / dry spells. Flooding as a result of excessive and heavy rainfall events. High temperatures (extreme heat).

A range of factors create **vulnerability** in the groundnut value chain, including a very high percentage of rural population (dependent on agriculture), very low levels of irrigation and a high reliance on rainfed agriculture, and high levels of poverty and unemployment (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 groundnut value chain in particular).

Stakeholders in Lilongwe and Nathenje added further granularity and insights to the understanding of vulnerability in the groundnut value chain, indicating that principal drivers of vulnerability in Malawi's groundnut value chain – at harvest and during post-harvest stages – are: **a lack of access to appropriate technology and equipment and facilities (such as adequate drying and storage facilities and other post-harvest infrastructure); lack of necessary knowledge and skills (including warehouse management); the reliance on traditional and manual techniques (rather than mechanised practices, such as for harvesting and threshing); and low purchasing power for costly tools such as moisture meters.**

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

Table 3-8- Top three climate change vulnerability factors identified for Malawi's groundnut 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
Lilongwe	Lack of/limited access to technology, equipment, facilities, infrastructure (e.g., for drying) Lack of/limited access to knowledge and skills (e.g., storage and pest control) Reliance on traditional, manual techniques (over mechanization).	Lack of/limited access to technology, equipment, facilities, infrastructure (e.g., for threshing and drying) Lack of/limited access to knowledge and skills (e.g., storage) Reliance on traditional, manual techniques (over mechanization).	Lack of/limited access to technology, equipment, facilities, infrastructure (e.g., for transport) Lack of/limited access to knowledge and skills (e.g., storage) Limited access to finance and low purchasing power for costly tools.
Nathenje	Lack of/limited access to technology, equipment, facilities, infrastructure (e.g., for harvesting) Lack of/limited access to knowledge and skills (e.g., storage) Low purchasing power / income levels	Lack of/limited access to technology, equipment, facilities, infrastructure (e.g., for and drying) Lack of/limited access to knowledge and skills (e.g., storage) Low purchasing power / income levels	Lack of/limited access to technology, equipment, facilities, infrastructure (e.g., for transport) Lack of/limited access to knowledge and skills (e.g., storage) Low purchasing power / income levels

In terms of **exposure**, one key factor that reduces the exposure of the groundnut value chain (relative to other crops in Malawi) is the much smaller fraction of cropland in the country that currently is dedicated to groundnut cultivation (very low, compared to the land used for staple crops).

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

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

Quantitatively, in our comparative climate change risk assessment, quantitatively the risk level of the groundnut value chain in Malawi scored: 13.846 out of 125, putting it at rank **13** 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

The limited available literature about post-harvest losses in the groundnut value chain in Malawi does not point to climatic factors as major causes of loss (Ambler, de Brauw, & Godlonton, IFPRI Discussion Paper 01632, 2017). Evidence from scholarly studies suggests that while weather is one of the factors implicated in losses during harvest, it is less salient than losses caused by mishandling (e.g., pods being left in the soil) (FAO, 2018b). Similarly, during processing, the major causes of loss are the groundnuts being spilled or blown away due to poor handling (Ambler, de Brauw, & Godlonton, IFPRI Discussion Paper 01632, 2017). At the drying stage, losses are caused by weevils, birds, and rodents (FAO, 2018b). During storage, the chief causes of losses are infestation and damage by rodents and other animals (Ambler, de Brauw, & Godlonton, IFPRI Discussion Paper 01632, 2017). While aflatoxin contamination is a concern at the storage stage, researchers note that the growth of mould and resultant aflatoxin contamination may be due to farmers' practices during shelling: "In most cases, to facilitate shelling, farmers sprinkle water to soften the pods not realizing that this practice will enhance mould growth leading to aflatoxin contamination" (FAO, 2018b). Thus, available literature leans towards non-climatic factors as drivers of post-harvest groundnut loss in Malawi: "Post-harvest losses in groundnut occur because of poor practices during harvesting, drying, stripping, shelling and storage resulting in lost pods and low-quality groundnut due to pests and mould growth" (FAO, 2018b). For this reason, scholars have also underscored: "While many policy recommendations have focused on storage technologies, these data suggest that technologies or better training that could lead to less waste during harvest and processing may be beneficial" (Ambler, de Brauw, & Godlonton, IFPRI Discussion Paper 01632, 2017).

Nevertheless, since **climatic conditions are relevant to mould and to aflatoxin infestation** (Feed the Future Peanut Innovation Lab, 2021) (aflatoxin production is heightened in warm and humid conditions, and thus exacerbated by flooding and heavy rainfall) (Natural Resources Institute, 2018), and since aflatoxin contamination is linked to an estimated 40% of loss of Malawi's exports of groundnuts (Manonga, 2023), **temperature and rainfall are important climate variables to be considered as hazards in this post-harvest value chain.**

While direct attribution of climate change to post-harvest losses of groundnut in Malawi 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 FAO (in the absence of corresponding data from APHLIS), the three stages where the largest volume of groundnut losses occurred in Malawi (in decreasing order) are (FAO, 2018b):

1. **Storage** – an average annual loss of 15% of the harvested crop
2. **Shelling** – an average annual loss of 9% of the harvested crop
3. **Stripping** – an average annual loss of 8% of the harvested crop.

Together, these three stages represent an average annual loss of nearly 32% (just under a third) of the losses in the post-harvest groundnut value chain in Malawi.

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

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 Malawi, ***these stages of the groundnut value chain are most at risk from climate change and thus should be prioritized for adaptation (loss-reduction) responses.***

Since these stages (where the largest share of post-harvest losses happens) of the groundnut value chain are still largely linked to **on-farm activities such as shelling, stripping and (on-farm) storage**, it is fair to surmise that the areas in Malawi where groundnuts are farmed are the dominant geographical locations for these losses, at these stages. Based on the map of groundnut growing areas in Malawi (below) (United States Department of Agriculture (USDA), n.d.), the districts of **Lilongwe** (accounting for 30% of groundnut production in 2015-2016) and **Mchinji** (15% in 2015-2016) may be prioritized for climate-responsive, risk-reduction interventions.

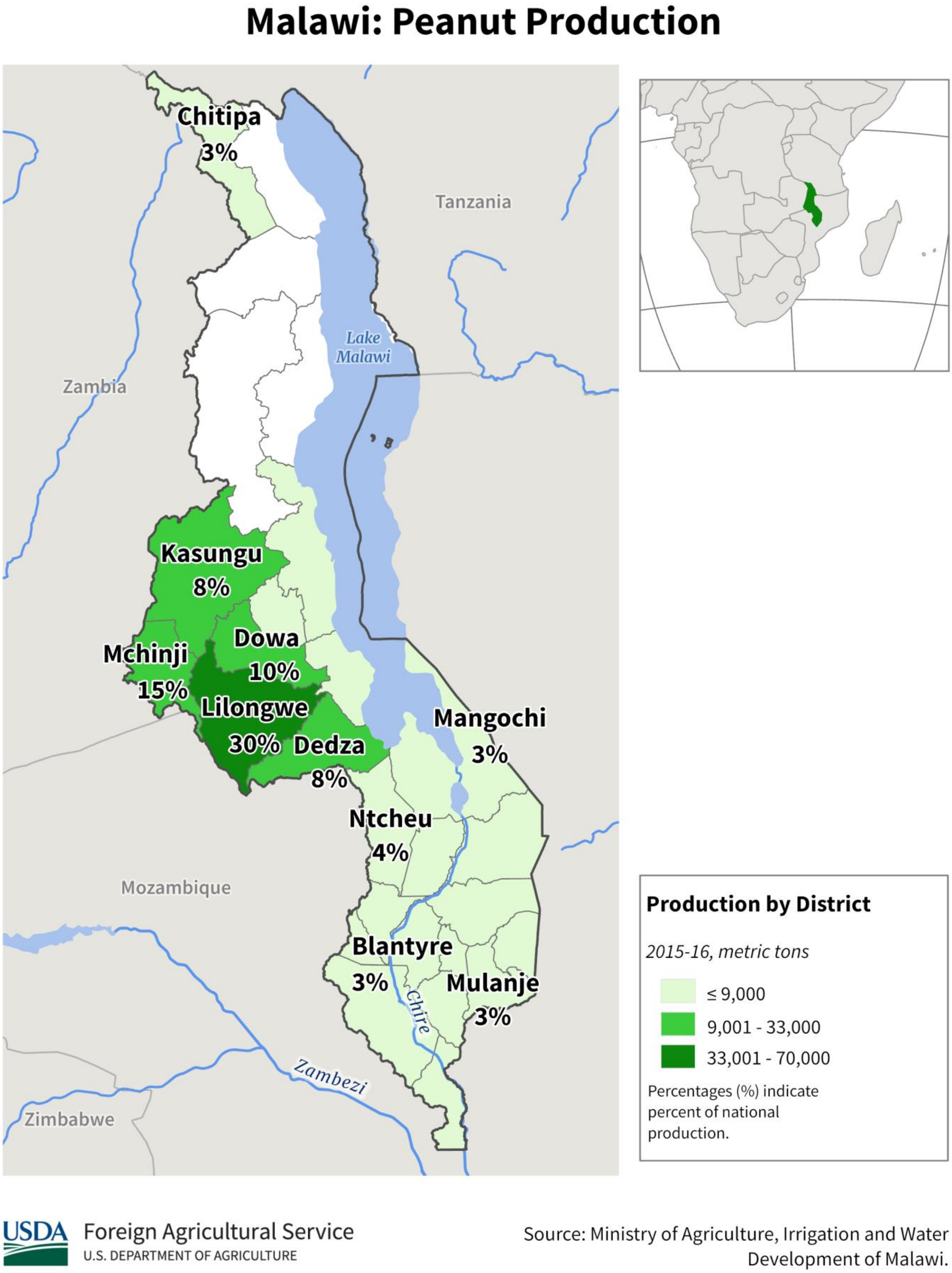


Figure 3-16 – Malawi: Groundnut Production by District, 2015-2016 (USDA, FAS)

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

- Kasungu,
- Lilongwe,
- Mzuzu,
- Salima.

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 **hazard 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 groundnuts in Malawi are presented in Table 3-10.

Table 3-10: Summary Climate Change Hazard Risk Table for Malawi 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 / drought			
	Extreme heat / heat waves			
	River and/or urban floods			
	Coastal floods	N/A	N/A	N/A
	Wildfire			
	Landslides			
	Cyclones	N/A	N/A	N/A
	Sea Level Rise	N/A	N/A	N/A
	OVERALL RISK LEVEL	*HIGH*	*HIGH*	*MODERATE*
GROUNDNUTS	Average temps			
	Rainfall variability			
	Average rainfall			
	Hot days over 35°C			
	Days with rainfall > 20mm			
	Avg. largest 1-day rain			
	Avg. largest 5-day rain			
	Water scarcity / drought			
	Extreme heat / heat waves			
	River and/or urban floods			
	Coastal floods	N/A	N/A	N/A
	Wildfire			
	Landslides			
	Cyclones	N/A	N/A	N/A
	Sea Level Rise	N/A	N/A	N/A
	OVERALL RISK LEVEL	*HIGH*	*HIGH*	*MODERATE*

Key:

High	
Medium	
Low	

4 Climate Analysis - Mitigation

4.1 COUNTRY AND SECTORAL CLIMATE CHANGE EMISSIONS BASELINE

4.1.1 National emissions

Malawi presented its National Greenhouse Gas Inventory (GHGI) in their Third National Communication (Minitry of Forestry and Natural Resources, 2021) to the United Nations Framework Convention on Climate Change (UNFCCC), as well as the First Biennial Update Report (Minitry of Forestry and Natural Resources, 2021). Agriculture and land-use change and forestry are the largest emitting sectors at ~10 million tonnes CO_2e and ~8 million tonnes CO_2e as of 2021, respectively (Figure) (Climate Watch, n.d.). While Malawi's national emissions have grown steadily in the last few decades, it still contributes only 0.05% of global emissions as of 2022 (Jones, et al., 2024).

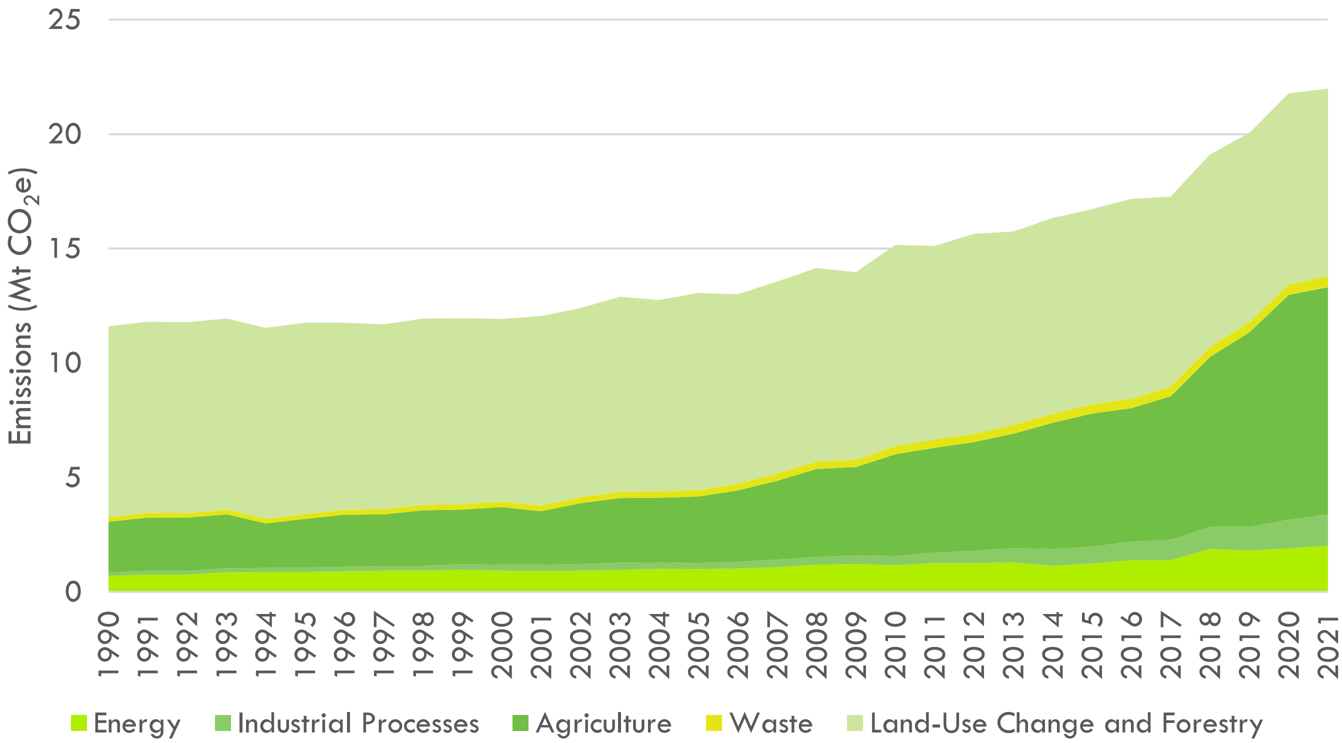


Figure 4-1 - Emissions (all GHG, $MtCO_2e$) across all sectors (total including LUCF) for Malawi (Climate Watch, n.d.)

4.1.2 Land use change

By using available land use change datasets, we can ascertain that a loss of forest cover occurred in Malawi between 1960 and 2019, with forest loss occurring over up to ~5%[2] of the land area in AGRA's target regions (see Figure below). Cropland expanded by up to ~5% of these areas in that period (Figure). Where deforestation occurred between 2001 and 2020, small-scale agriculture was the dominant land use which replaced forest cover (Table) (Masolele, et al., 2024).

[2] Calculated using zonal statistics in QGIS from HIstoric Land Dynamics Assessment (HILDA+) data layers (HILDA+).

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

	Large-Scale Cropland	Pasture	Mining	Small-Scale Cropland	Roads	Other Land With Tree Cover/ Regrowth	Plantation Forest	Coffee	Settlement	Tea Plantation	Water	Oil Palm	Rubber	Cashew	Cocoa
Balaka	2.4%			71.1%	15.7 %	3.6%			6.0%		1.2%				
Chikwawa	6.6%	<1%	6.6%	75.7%	<1%	3.1%	<1%		3.0%		3.3%			<1%	
Dedza	31.7%	1.5%	<1%	54.0%	<1%	1.4%	1.4%		6.9%		<1%				1.2%
Dowa	12.3%	<1%		78.1%	<1%	<1%			8.8%						
Kasungu	9.6%	4.8%	<1%	79.6%	<1%	3.5%			2.1%		<1%				
Lilongwe	30.0%	<1%	2.5%	45.5%		2.6%	<1%		18.6%						
Machinga	16.4%	1.3%	<1%	75.7%		3.1%			3.3%						
Mangochi	3.3%	<1%	1.1%	86.8%	<1%	4.4%			2.3%		1.0%			<1%	
Mchinji	10.0%	1.2%		76.0%		5.0%			7.9%						
Mzimba	5.7%	4.5%	<1%	84.5%	<1%	1.2%	<1%		2.5%	<1%	<1%	<1%	<1%	<1%	<1%
Nkhata Bay	2.0%	<1%	1.6%	88.4%	<1%	1.8%	<1%		4.1%	<1%	<1%	<1%	<1%	<1%	<1%
Nkhotakota	<1%	<1%	<1%	95.8%	<1%	<1%			1.8%		<1%			<1%	
Nsanje	6.6%	<1%	3.8%	75.5%		2.5%			4.2%		6.6%				
Ntcheu	10.7%	<1%	<1%	76.5%		<1%	<1%		9.7%		<1%				1.4%
Ntchisi	2.6%	<1%		92.7%	<1%				3.5%						
Rumphi	29.0%	1.7%	<1%	62.7%		5.6%	<1%		<1%						
Salima	8.4%	<1%	<1%	82.8%	<1%	<1%			7.1%		<1%				
Zomba	19.0%		<1%	59.5%					19.5%		1.5%				

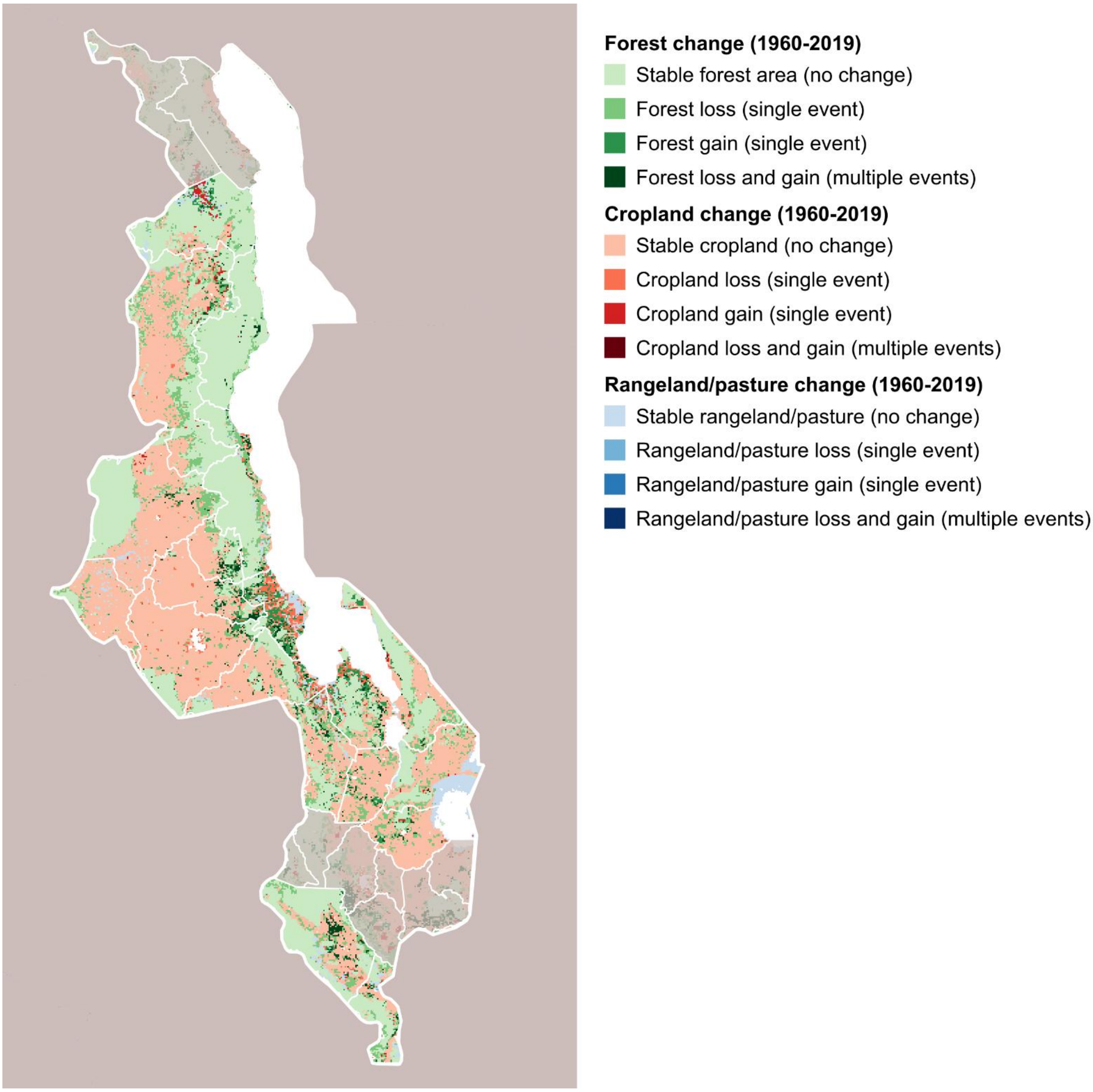


Figure 4-2 - Change in cover for land use categories forest, rangeland/pasture and cropland in AGRA target regions across Malawi between 1960 and 2019 (HILDA+)

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 groundnuts (Poore & Nemecek, 2019). Farm activities account for the bulk of emissions from both maize and groundnuts (Figure). Losses account for a significant proportion of emissions (Figure), particularly in smallholder value chains.

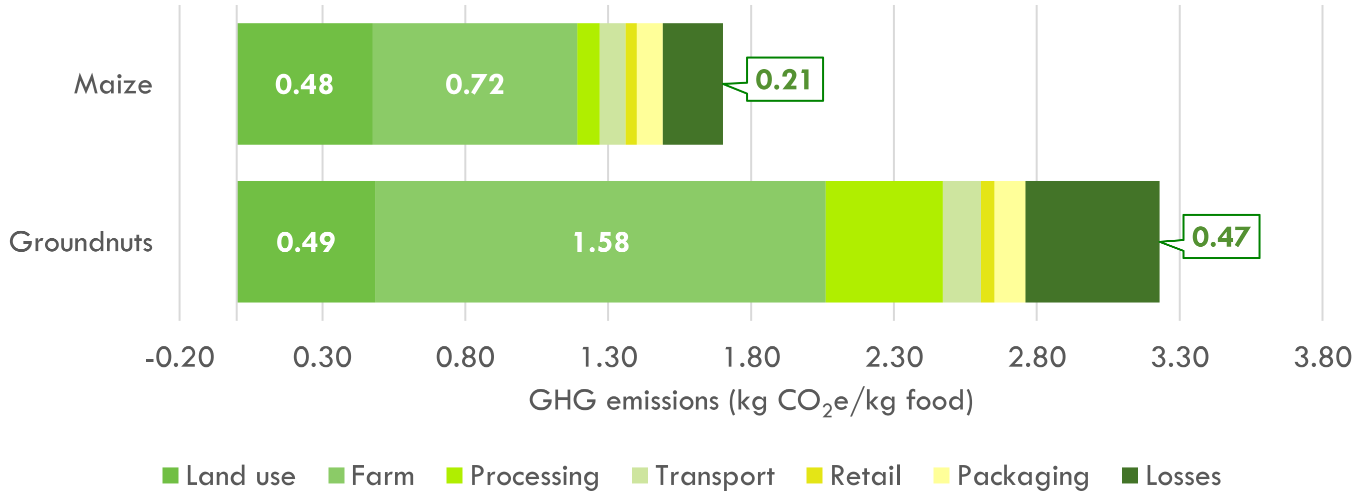


Figure 4-3 - Average GHG emissions (kgCO_2e/kg food) for agricultural commodities across value chains (Poore & Nemecek, 2019)

Typical losses and emissions sources across agricultural value chains are depicted in Figure 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.

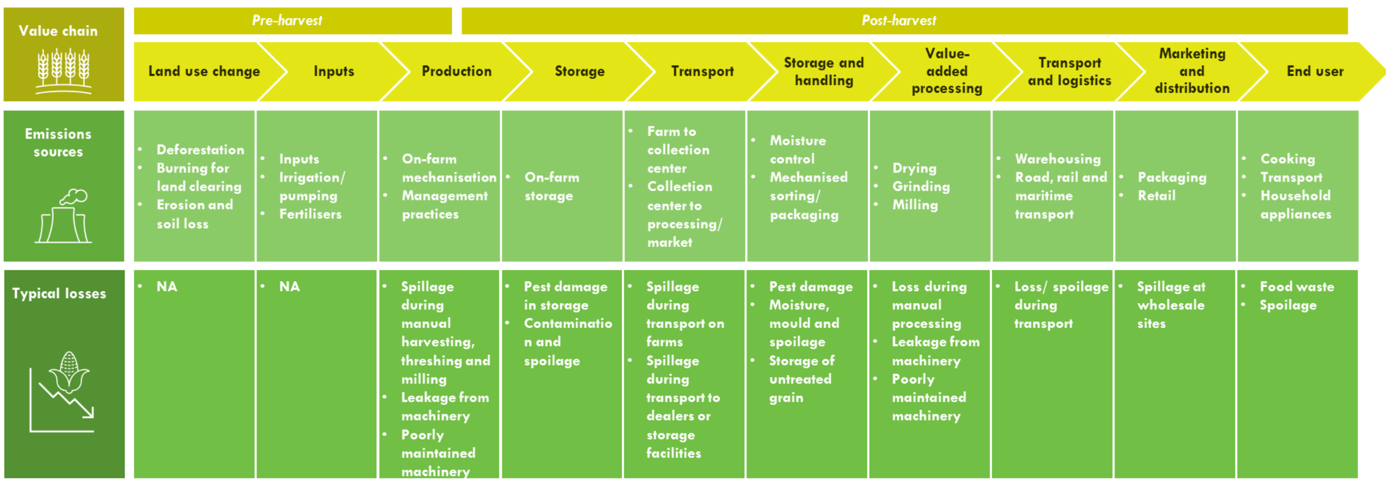


Figure 4-4 - Typical sources of emissions and food losses across agricultural value chains (Analysis from report authors)

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

4.2.1 Emissions related to food loss

Food loss along agricultural value chains risks not just the loss of edible food, but the waste of the natural resources associated with its production, such as land and water. The inefficient use of natural resources can be considered to have its own environmental footprint, with carbon emissions associated with food loss being among them.

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 phase, estimated at 6.3% of total production (Table 4-2). Further analysis on food losses is discussed on chapter 5.

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

Value chain stage	Losses (%)	Cause(s)	Reference
Harvesting, field drying	6.3%	N/A	(APHLIS, 2024) (FAO Food loss and waste database, 2024); Golob (1981); Boxal, et al., (2002)
Threshing/ shelling	1.4%	Inefficient manual beating of cobs in polypropylene bags.	
Winnowing	N/A	N/A	
Drying	4.0%	N/A	
Transport to farm	2.4%	N/A	
On-farm storage	4.2%	Storage of untreated and insufficiently dry grain leads to spoilage, insect damage.	
Transport to market	1.6%	N/A	

4.2.2.2 Groundnuts

On-farm post-harvest losses in the groundnut value chain occur as a result of inefficient shelling practices, as well as poor storage and transport practices. The largest reported losses occur during storage, estimated at up to 15% of total production (Table). Further analysis on food losses is discussed on chapter 5.

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

Value chain stage	Losses (%)	Cause(s)	Notes on loss values	Reference
Harvesting, field drying	6.0%	Inefficient lifting methods	Values for losses for groundnuts were taken from the FAO FLWD, as no information was provided via APHILIS.	(FAO Food loss and waste database, 2024)
Threshing/ shelling	11.0%	Inefficient shelling machinery		
Winnowing	N/A	N/A		
Drying	5.0%	Lack of effective drying facilities		
Transport to farm	14.0%	Spillage		

On-farm storage	15.0%	Ineffective storage structures and storage of untreated produce		
Transport to market	N/A	N/A		

4.2.3 Emissions associated with food loss

The emissions associated with food loss across the agricultural values chains considered by the RE-GAIN Programme in Malawi, based on smallholder production values, are 1 177 465 tCO_2e from maize and 917 148 tCO_2e from groundnuts.

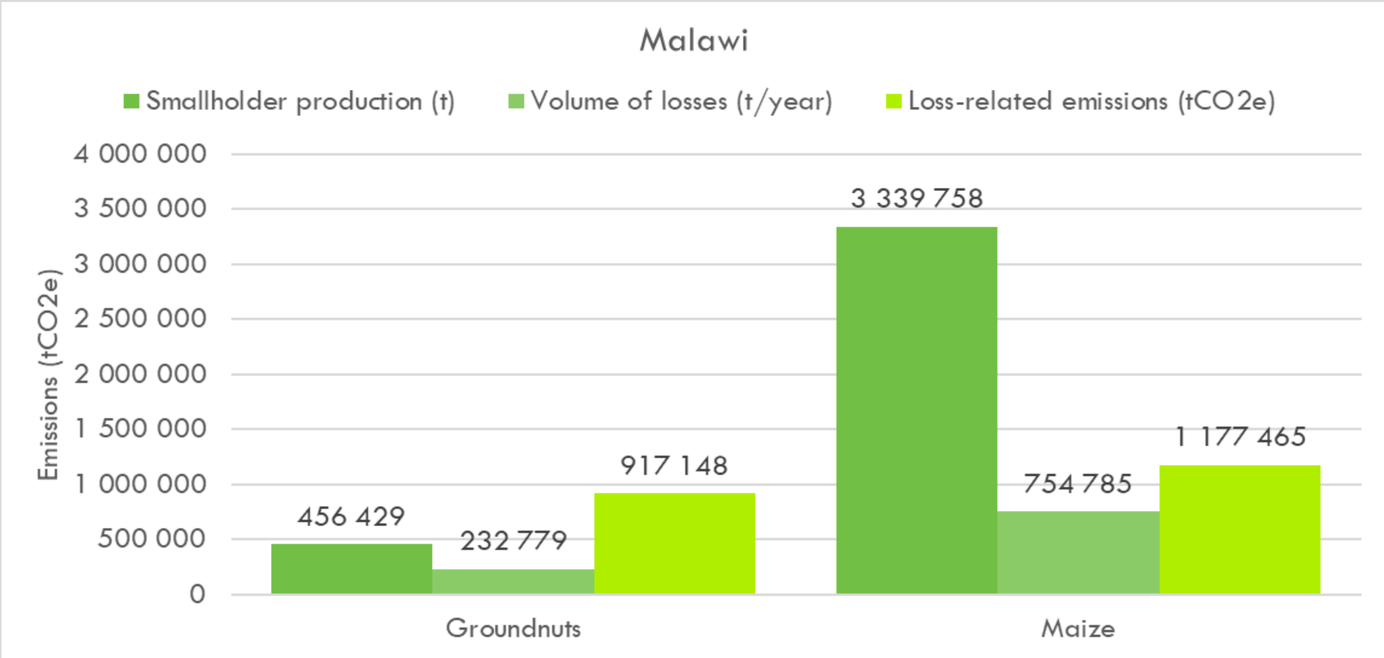


Figure 4-5 - Estimated emissions (tCO_2e) from post-harvest losses

A note on the calculation methodology: Using the total maximum losses possible under the loss scenarios presented in the tables above, a possible total loss (%) per commodity can be calculated, as presented in Table 4-4 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 et al. (2016) and have been used in several studies to estimate emissions.

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

Country	Crop	Smallholder production (t)	Loss rate (%)	Volume of losses (t/year)	Loss-related emissions (tCO2e)
Malawi	Groundnuts	456 429	51%	232 779	917 148
	Maize	3 339 758	23%	754 785	1 177 465
Total		**3 796 187**	**74%**	**987 564**	**2 094 613**

4.3 COUNTRY AND SECTORAL CLIMATE CHANGE EMISSIONS PROJECTIONS

The GHG inventory developed by Malawi provides projected emissions to 2030 for key sectors under business-as-usual (BAU) and alternative scenarios, which are also used as part of the NDC. The BAU emissions projections for Malawi as stated in the NDC (Republic of Malawi, 2021) **are provided below (Figure 4-6, see also Figure above).** Emissions from the agricultural sector are projected to increase between 2020 and 2030 under the BAU emissions scenario, reaching 7.7 $MtCO_2e$ by 2030 (Figure 4-6) (Republic of Malawi, 2021).

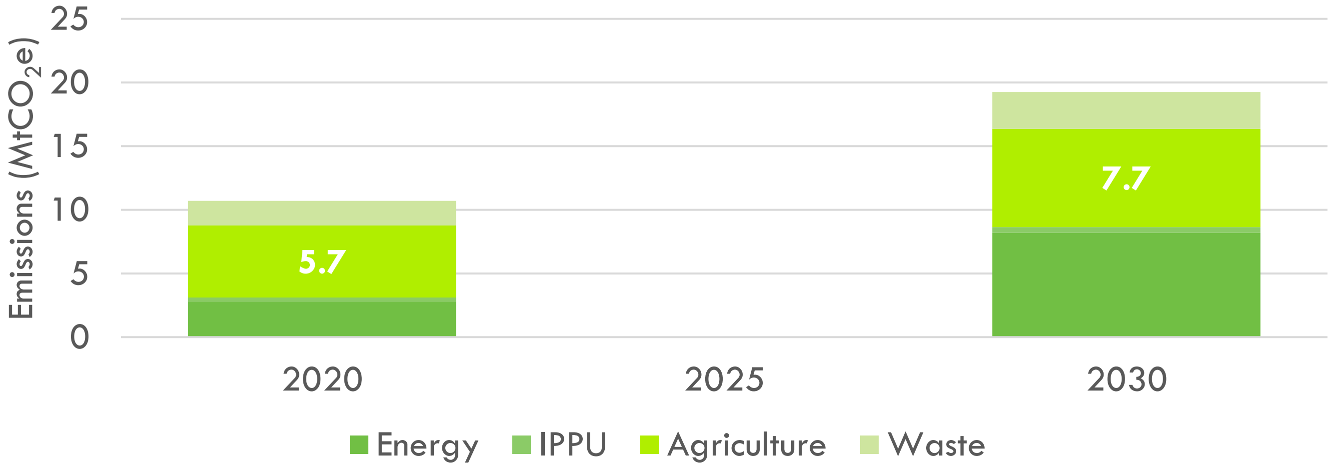


Figure 4-6 - Projected emissions across key sectors in Malawi (Republic of Malawi, 2021)

4.4 CROP VALUE CHAINS CLIMATE CHANGE EMISSIONS PROJECTIONS

The OECD-FAO Agricultural Outlook 2023–2032 (OECD & FAO, 2023a) **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, 2023a).

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, 2023a). 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, 2023a).

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

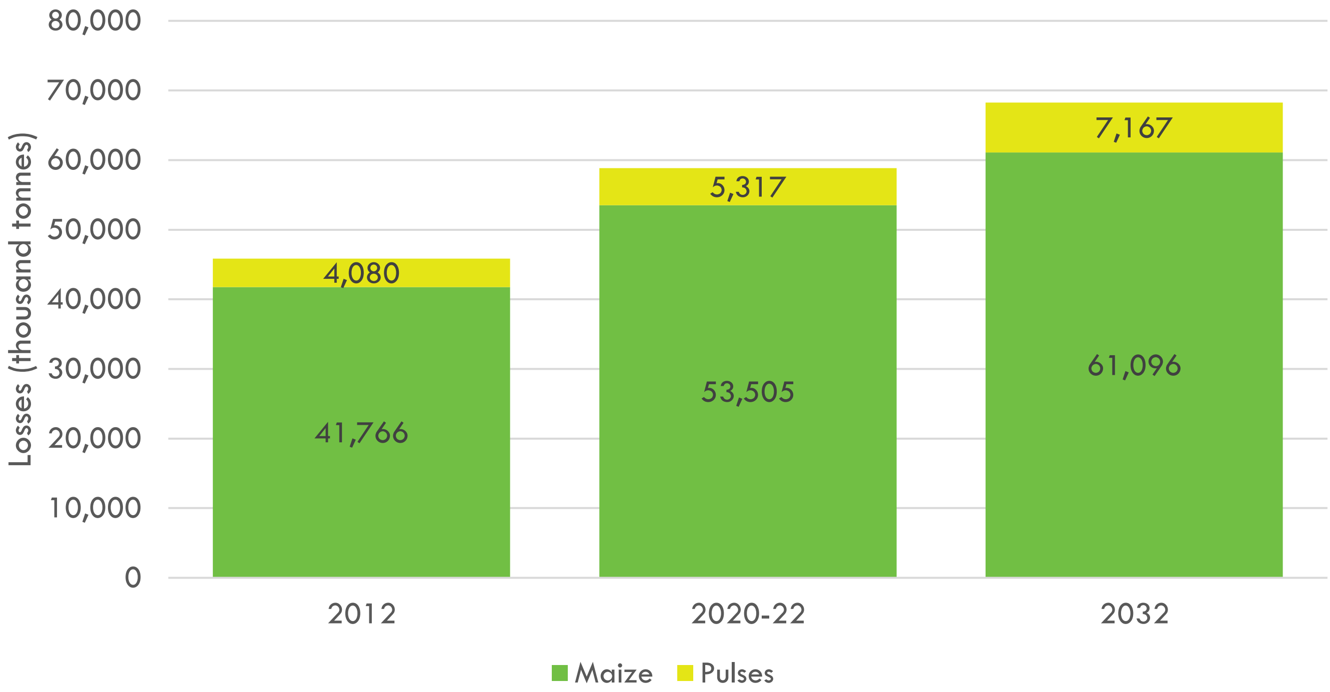


Figure 4-7 - Projected losses across global agricultural value chains for key commodities towards 2032 (OECD & FAO, 2023b)

By using available estimates of losses as presented in Table 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 (OECD & FAO, 2023b) **to calculate potential post-harvest losses and associated emissions for the 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 (OECD & FAO, 2023b) provides projected estimates of changes in production, yields and harvested area for key commodity groups across SSA. By using the data available from Table and its sources, the OECED & FAO (2023b) projections were used to calculate estimates for production of the crops in the target countries. These values assume that loss estimates remain unchanged by both adaptation interventions and climate change impacts.

Table 4-5 - Estimated emissions (tCO_2e) for the year 2032 calculated using projected losses per commodity, total smallholder annual production (tonnes) and emissions factors for food loss emissions (Porter, Reay, higgins, & Bomberg, 2016)

Country	Crop	Projected production 2032 (t)	Projected losses 2032 (t/year)	Projected loss-related emissions 2032 (tCO2e)
Malawi	Groundnuts	510 714	260 464	1 026 228
	Maize	4 046 378	914 481	1 426 591
Total		**4 557 092**	**1 174 945**	**2 452 819**

Without intervention, emissions related to post-harvest losses on smallholder farms are expected to increase by between ~12% and ~21% across the target countries (

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

). **For Malawi, this could amount to 1 426 591 tCO_2e for maize and 1 026 228 tCO_2e for groundnuts by 2032 (Table).** This presents the minimum expected losses as climate change is likely to exacerbate these numbers.

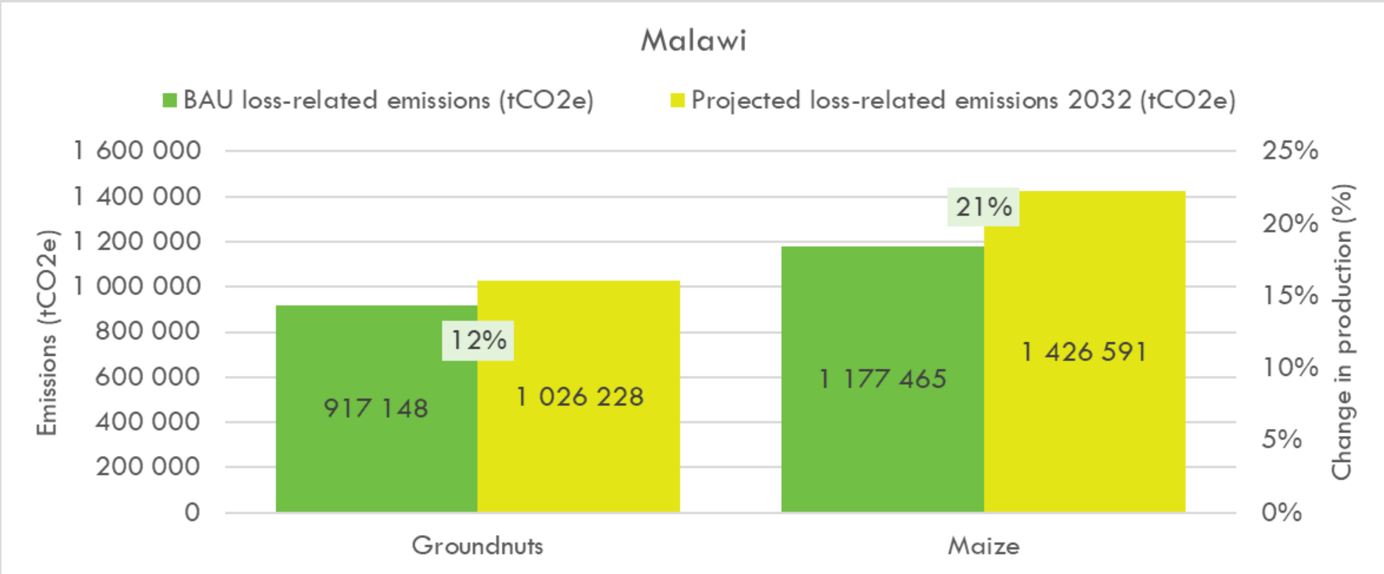


Figure 4-8 - Estimated emissions from post-harvest losses in 2022 and 2032 for key crops in Malawi, percentage values indicate projected increase in emissions

5 Design of Food Loss Reduction Solutions

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

5.1.1 Maize

As previously mentioned, agriculture accounts for about 80% of the total employment in Malawi (CIAT, World Bank, 2018) **and contributes 40% to the nation's Gross Domestic Product (GDP)** (Republic of Malawi, 2021). Maize, as the country's staple food crop, plays a crucial role in national food security. Food security in Malawi is typically measured by the availability and accessibility of maize, with per capita maize consumption being among the highest in Africa (Erenstein, Jaleta, Sonder, Mottaleb, & Prasanna, 2022). Over 1.6 million smallholder and subsistence farmers rely on maize production for their livelihoods, with estimates suggesting that up to 97% of small-scale producers grow maize, which occupies around 60% of the total cropped area (CIAT; World Bank, 2018). Major maize-growing regions include Kasungu, Lilongwe, Blantyre, Machinga, and Mzuzu (Figure 3-15). However, climate extremes, such as droughts, lead to an average loss of 4.6% in maize yields (CIAT, World Bank, 2018).

Although maize receives substantial government support, its production growth has lagged behind population increases. Moreover, smallholder farmers achieve yields significantly below their potential. While the potential yields for maize are between 8 to 10 tonnes per hectare, smallholder farmers typically produce only 1 to 2.1 tonnes per hectare (FAO, 2018a). Maize production in Malawi has grown steadily between 1992 and 2022 (Figure 5-1) with annual yields fluctuating primarily due to changes in climatic conditions and rainfall (FAO, 2022). Local production can fulfill domestic demand and exports are generally low (Figure 5-2) (FAO, 2022).

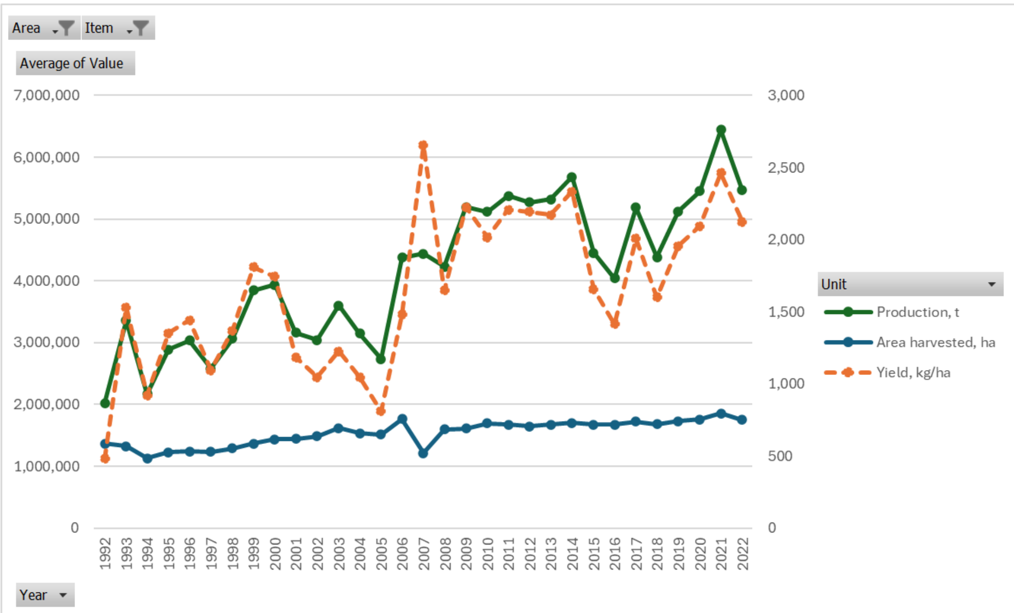


Figure 5-1 - Maize production, harvested area and annual yields in Malawi, 1992-2022 (FAO, 2022)

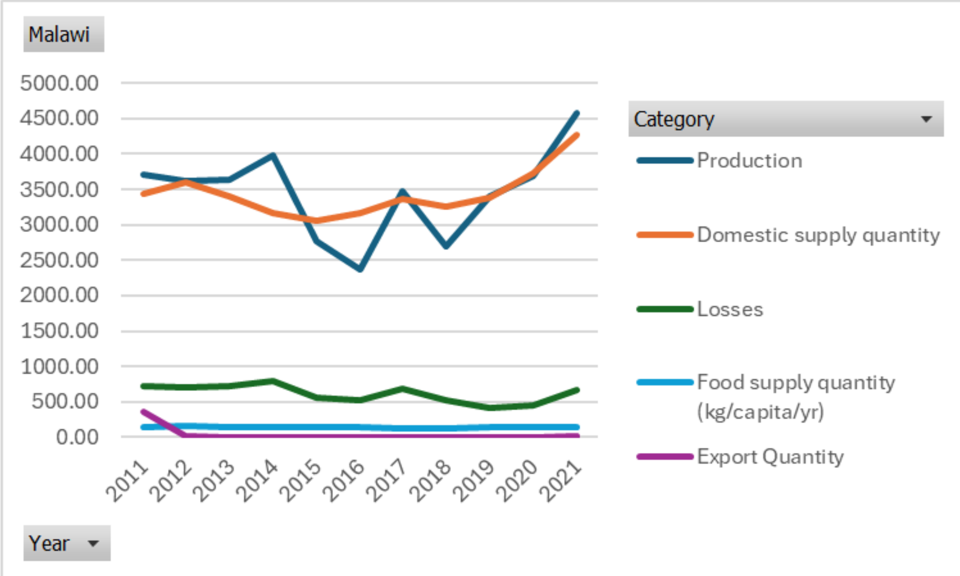


Figure 5-2 - Maize domestic supply, exports, per capita consumption, and production in Malawi, 2011-2021 (FAO, 2022)

In Malawi, maize plays a crucial role not only in food security but also in the livestock industry. It serves as a primary ingredient in livestock feed, and maize residues, typically low in market value, become economically significant when used as feed or livestock bedding, which eventually decomposes into organic manure (FAO, 2018a).

Green maize, largely produced as a winter crop on wetlands using residual moisture, is sold in three forms for income generation: fresh for consumer processing, boiled, and roasted (FAO, 2018a). Fresh maize is sold by both male and female vendors, boiled by women, and roasted mostly by men at roadside stalls (FAO, 2018a). Conversely, dry maize primarily serves food security, with surplus production informally traded within communities or at local trading centres (FAO, 2018a).

The dry maize value chain in Malawi involves smallholder farmers, who dominate production, averaging 0.4 hectares per household with yields around 1 tonne per hectare (FAO, 2018a). Postharvest losses in the maize value chain in Malawi vary based on farming practices such as the timing and methods of harvesting, processing, and cleaning (FAO, 2020).

Harvesting involves two methods: stooking, where maize stalks are cut and stacked in heaps to dry and prevent mould, and direct harvesting, where cobs are manually removed from the stalk and transported to a central heap (FAO, 2018a). Post-harvest, maize is carried from fields in baskets or sacks and sometimes by bicycle or oxcart. Dehusking, done manually due to a lack of technology, is often combined with harvesting to prevent theft, introducing potential losses during transport (FAO, 2018a).

Shelling, the manual separation of kernels from the cob, remains a family task despite the availability of hand-shelling technologies, which have seen limited use (FAO, 2018a). Winnowing, the manual separation of grain from chaff, precedes bagging but can result in some losses as livestock may consume the grain (FAO, 2018a). Milling transforms the grain into flour through bran removal and grinding, using milling machines available for a fee (FAO, 2018a).

Following harvesting, drying, dehusking, and shelling, smallholder farmers sell their maize to small-scale traders. These traders, in turn, supply medium- and large-scale traders or market institutions. Retailers and small-scale millers acquire grain from small-scale traders for consumer sales, while industrial processors source from medium and large-scale traders, selling processed products to retailers (FAO, 2018a).

Various studies have examined the extent of post-harvest losses, with maize food loss data compiled from different sources presented in Table 5-1. There is considerable variation is the estimated losses for threshing and shelling, household-level storage, and market storage. Overall, the most critical loss points for maize in Malawi are harvesting/field drying, threshing and shelling, household-level storage, and drying. Maize is susceptible to moisture, aflatoxin contamination, and pest and rodent infestations during storage. To mitigate these risks, it is essential to dry the grain to a moisture content of 12-13% before storing it (Ayalew, et al., 2017). The lowest losses occur during transportation to the market.

Different sources have different assessments on where the largest food losses occur in the maize value chain in Malawi. Fost instance, the FAO (2018a) indicates that significant losses occur in Malawi's maize production, with 58% in quantity and 22% in quality, primarily during harvesting and subsequent on-farm operations. Key loss points include stooking, ear picking, shelling, and on-farm storage. Stooking, which involves manually stacking cut maize stalks upright in the field for drying, results in 10% quantity losses and 6% quality losses due to insect and rodent infestations and mould growth (FAO, 2018a). During ear picking, a 14% loss occurs, often because children or hired labourers, who plan to collect maize for personal use later, leave some ears behind (FAO, 2018a). Shelling, done by beating maize cobs in a polypropylene bag or using inefficient motorised shellers, leads to 14% quantity losses and 5% quality losses because of spillage and broken grains (FAO, 2018a). Storage is another critical stage, with 20% quantity losses and 9% quality losses caused by pests, rodents, and mould contamination, exacerbated by the use of traditional granaries for storing maize cobs and grains (FAO, 2018a).

Table 5-1 - Comparison of Maize food losses in the different stages of the value chain in Malawi

Value chain stage	APHLIS database (2022)	FAO Food loss and waste database (2021)	FAO Food loss analysis study (2018a)
Harvesting/ field drying	6.4%	6.31%	8.5%
Further drying	4.0%	3.98%	
Threshing and shelling	1.3%	1.36 – 14.0%	4.2%
Transport from field	2.4%	2.40%	
Household-level storage	2.5%	7.94%	17.5%
Transport to market	1.7%	1.65%	
Market storage	2.7%	3.18%	
Overall:	17.0%		

A general overview of the maize value chain in Malawi, covering key stages, processes, stakeholders, climate data, and potential solutions to reduce food losses is presented in the Table 5-2.

Table 5-2 - Overview of Maize food losses in Malawi in the different steps in the value chain, relevant parameters, and suggested solutions

FSC Stage/Process	Processes	% Losses*	Cause of losses	Affected stakeholders	Climate aspects	Suggested solutions
Harvesting						
Reaping and postharvest drying/stooking	Cutting/gathering the cobs, manually or using mechanical harvesters Field drying in stooks	6.4%	Inadequate equipment and technologies for harvesting; wrong timing; leaving some cobs in the field	Farmers	Heat stress for workers/farmers and animals, increased humidity/ moisture of crops and fungi development Rains, winds	Capacity building training on harvesting techniques and harvesting tools Capacity building on drying
Dehusking and shelling of cobs	Manual or mechanical shelling, using manual and mechanical shellers	1.3%	Mechanical damage	Farmers	Rains, winds, temperature	Capacity building trainings on proper dehusking and shelling techniques
Hauling (transport from field to the farm)	Transport from the field to the farm, carrying by hand or by using various vehicles	2.40%	Spillage	Farmers	Rains, winds	Improved transportation solutions
Post harvest processes (on-farm)						
Drying	Additional drying using cribs, tarpaulins, and similar solutions	4.0%	Mold, insects, rodents, livestock foraging	Farmers	Rains, winds, temperature	Plastic sheets and tarpaulins, rectangular cribs
On-farm storage	Storage of shelled maize in bags, baskets, silos, or other available storage facilities	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	Milling using manual, partially mechanised or fully mechanised small-scale mills	Not Reported	Spillage, contamination with foreign materials	Millers	Rains, winds	
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	1.65%	Spillage, contamination with foreign materials	Aggregators/ collectors and traders	Rains, winds	Plastic hermetic bags; non-hermetic polypropylene bags
Grading and packing	Sorting, pre-cleaning, re-packaging and packaging	Not Reported	Spillage, qualitative losses	Collectors and traders	N/A	Plastic hermetic bags; non-hermetic polypropylene bags
Storage	In bulk and/or in bags	2.7 – 3.18%	Spillage, qualitative losses	Storage companies, warehouses	N/A	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	N/A	
Secondary processing	Further processing into roller meal, flour, animal feed, products for the snack and brewing industry, etc.	Not Reported	Spillage, qualitative losses	Secondary processors	N/A	

* Compiled using the APHLIS database (2022) and FAO Food Loss and Waste Database (2021).

5.1.2 Groundnuts

Groundnuts have been cultivated in Malawi since the mid-19th century, predominantly by around 3 million smallholder farming families (FAO, 2018b). This crop is often rotated with maize and tobacco, and approximately twelve varieties are grown in different regions (FAO, 2018b). The central and southern areas, including Kasungu, Lilongwe, Machinga, and Blantyre, contribute to 75% of the total groundnut production area. Currently, about 10% of Malawi's groundnut yield is exported (FAO, 2018b).

The increasing popularity of groundnuts, a non-staple crop, signals a shift among Malawian farmers from subsistence farming towards more commercially viable agriculture. However, production growth is constrained by unpredictable climatic conditions, pests, diseases, poor soil fertility, and traditional farming practices (Minde, 2008).

Groundnuts are highly valued not only for their diverse culinary uses—such as raw, roasted, or boiled snacks, and seasoning for various leafy vegetables—but also for their contributions as a source of vegetable oil, protein, and as a raw material in animal feed and confectionery (FAO, 2018b). Despite their economic potential, the export capacity of groundnuts remains underutilised due to limited production (FAO, 2018b).

Recognising the importance of groundnuts for cash income, employment, and post-harvest loss reduction, the Malawian Government has prioritised this crop (FAO, 2018b). Recent initiatives by the government and other partners have aimed to boost groundnut production and marketing (FAO, 2018b).

From 1992 to 2022, the area dedicated to groundnut cultivation in Malawi has steadily expanded, reflecting the crop's growing importance (Figure 5-3) (FAO, 2022). Nonetheless, annual yields have been inconsistent, with a significant decline noted in 2015-2016 (FAO, 2022). Production of groundnuts has been relatively stable, apart from a drop in production volumes in 2015 and 2016 (Figure 5-4) (FAO, 2022).

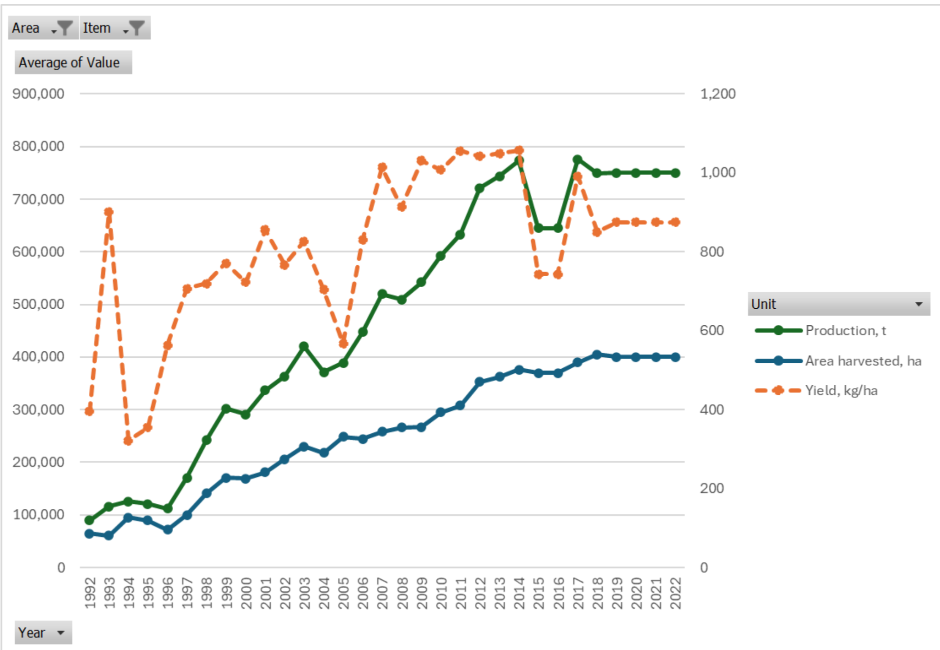


Figure 5-3 - Harvested areas, production volumes and annual yields of groundnuts in Malawi, 1995-2022 (FAO, 2022)

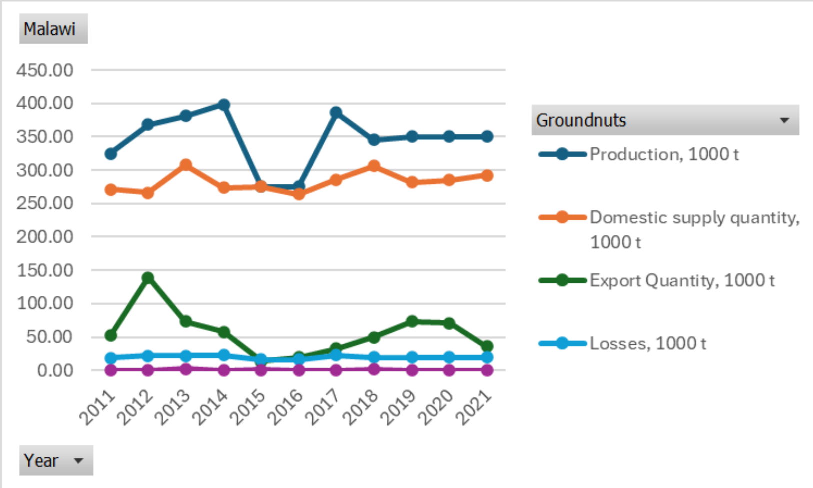


Figure 5-4 - Production, domestic supply, export and losses of groundnuts in Malawi, 2011-2021 (FAO, 2022)

In Malawi, the groundnut subsector is characterised by two main supply chains: informal (unregulated) and formal (regulated) (FAO, 2018b). The informal supply chain involves mainly smallholders, small-scale traders, and vendors, while the formal supply chain includes smallholder farmers, assemblers purchasing groundnuts from individual smallholders and small-scale traders, who then sell to large-scale traders (FAO, 2018b). Cottage shellers also play a significant role in the formal chain (FAO, 2018b).

Groundnuts are typically planted in December, with weeding, disease, and pest control continuing until March (FAO, 2018b). Harvesting begins in April, involving manual digging with hand-hoes, sun drying, and hand-stripping, and coincides with the start of the marketing season (FAO, 2018b). Peak marketing occurs between June and August, tapering off from September until the next harvest (FAO, 2018b).

The supply chain to consumers involves various players: small and large-scale traders, assemblers, transporters, warehouse agents, vendors, cottage shellers, and processors (FAO, 2018b). Key activities along the chain include harvesting, drying, transportation, shelling, storage, trading, and processing (FAO, 2018b).

Traditionally, groundnut harvesting in Malawi is carried out by women, who use hoes to lift the groundnut haulms and pluck the nuts (FAO, 2018b). Haulms are stacked with nuts facing upwards to facilitate drying and prevent mould, using methods like the Mandela Cork for drying in the field (FAO, 2018b). The harvested nuts are then transported to farms in baskets or plastic bags, with some farmers using bicycles or oxcarts (FAO, 2018b).

Shelling, which removes the nut from the pod, is another crucial step. While commercial shellers are available, most smallholders shell by hand, often sprinkling water to ease the process—a practice that can cause mould and aflatoxin contamination (FAO, 2018b). Hand shelling is often done simultaneously with maize shelling, potentially leading to contamination and involving child labour (FAO, 2018b).

Groundnuts are stored either unshelled or shelled in structures such as traditional granaries and polypropylene bags, often within the home. Smallholder farmers sell their produce at various supply chain stages, from farmgate sales to local markets, using oxcarts, bicycles, or by headloads, often in polypropylene bags (FAO, 2018b).

The formal supply chain involves cottage shellers and industrial processors who turn nuts into products like peanut butter, cooking oil, and snacks (FAO, 2018b). Groundnut cake, a by-product of oil production, is used in livestock feed (FAO, 2018b). Processed products are marketed domestically and for export. Shelled groundnuts serve as a key intermediary product before further processing (FAO, 2018b).

Various trader categories buy groundnuts from smallholders, including itinerant buyers who travel to purchase small quantities, assemblers who buy and store larger quantities, and large-scale traders who often have warehouses and transport fleets (FAO, 2018b). These traders sell groundnuts to processors and for export.

Critical loss points (CLPs) in the groundnut supply chain occur during drying, farm storage, shelling, and warehouse storage, with quantitative and qualitative losses reported (FAO, 2018b). During drying, losses are caused by pests like weevils, rodents, and birds, as well as livestock and passers-by. Weeds can also exacerbate pest problems (Ambler, de Brauw, & Godlonton, 2017).

At the stripping stage, losses occur when pods are left unstripped or spill during transfer from drying points. Weeds may cause pods to remain in the soil, and pests damage stored groundnuts if storage structures are not adequately protected (Tsusaka, Singano, Seetha, & Kumwenda, 2017).

Storage facilities used by smallholders include polypropylene bags, traditional granaries, and metal drums (Tsusaka, Singano, Seetha, & Kumwenda, 2017). Unprotected storage can lead to rodent and weevil infestations, and losses are high when groundnuts are stored in open spaces (Ambler, de Brauw, & Godlonton, 2017).

To address post-harvest losses, the Malawian Government has recommended using Purdue Improved Crop Storage (PICS) bags to reduce losses from aflatoxin and weevil infestation during storage. Aflasafe, a biocontrol measure, has been introduced to prevent aflatoxin contamination in groundnuts and minimise losses both in the field and during storage (FAO, 2018b).

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

Table 5-3 - Overview of Groundnut food losses in Malawi in the different steps in the value chain, relevant parameters, and suggested solutions

FSC Stage/Process	Processes	% losses *	Cause of losses	Affected stakeholders	Climate aspects	Suggested solutions
Harvesting						
Harvesting/ lifting	Harvesting using primarily hand hoes	6.3%	Inadequate equipment and technologies for harvesting; wrong timing	Farmers	Heat stress for workers/farmers and animals, increased humidity/ moisture of crops and fungi development, rains, winds	Capacity building training on harvesting techniques and harvesting tools
Drying	Drying in the field after harvesting using cribs, tarpaulins, and similar solutions	4%	Aflatoxins, pest and rodent attacks, birds	Farmers	Heat stress for workers/farmers and animals, increased humidity/ moisture of crops and fungi development, rains, winds	Plastic sheets and tarpaulins
Hauling (transport from field to the farm)	Transport from the field to the farm, carrying by hand or by using various vehicles	2.4%	Spillage	Farmers	Rains, winds	Improved transportation solutions
Post harvest processes (on-farm)						
Stripping	Stripping of pods, usually manual	QN 14%, QL 1%	Pods are not stripped, left on the haulms	Farmers	Rains, winds	Capacity building on stripping tools, technologies and techniques
On-farm storage	Storage in polypropylene bags, in dwellings, baskets, etc.	4.2%	Mold, pests/rodents, discoloration	Farmers	Heat/ high temperatures	Metal and plastic silos, sheds, plastic and hermetic bags, baskets and cribs, solid brick bins, Insecticides/ fumigation
Shelling	Manual or machine shelling, with water sprinkled to soften the pods for easy shelling	1.4%	Spillage, moisture, contamination with foreign materials, high percentage of broken or damaged nuts due to machine shelling	Farmers	Rains, winds	Capacity building on improved shelling tools, technologies and techniques
Transport, logistics, further processing						
Marketing	Selling in bulk by farmers, picked up by aggregators/commercial buyers	Not Reported	Spillage, contamination with foreign materials	Aggregators/ collectors and traders	N/A	Plastic hermetic bags; non-hermetic polypropylene bags
Storage	In bulk and/or in bags, in warehouses	Not Reported	Rodents and weevil infestations	Storage companies, warehouses	N/A	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	N/A	
Secondary processing	Further processing into peanut butter, cooking oil, powder, animal feed, products for the snack and brewing industry, etc.	Not Reported	Spillage, qualitative losses	Secondary processors	N/A	

*Quantitative (QN) and Qualitative (QL) (FAO, 2018b).

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

This sub-chapter provides an overview of the most suitable physical and non-physical food loss reduction solutions for Malawi. RE-GAIN Programme aims to increase awareness of smallholder farmers in Malawi 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 Malawi 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 Malawi. The proposed FL-RS in those subchapters have been short-listed considering the specific context of Malawi 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 5-4.

Table 5-4 - Indicative Awareness Raising and Capacity Building elements of RE-GAIN Programme in Malawi

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

	Awareness Raising	Capacity building
		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 Fl-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 Malawi, 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 Malawi, 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 Malawi.

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.

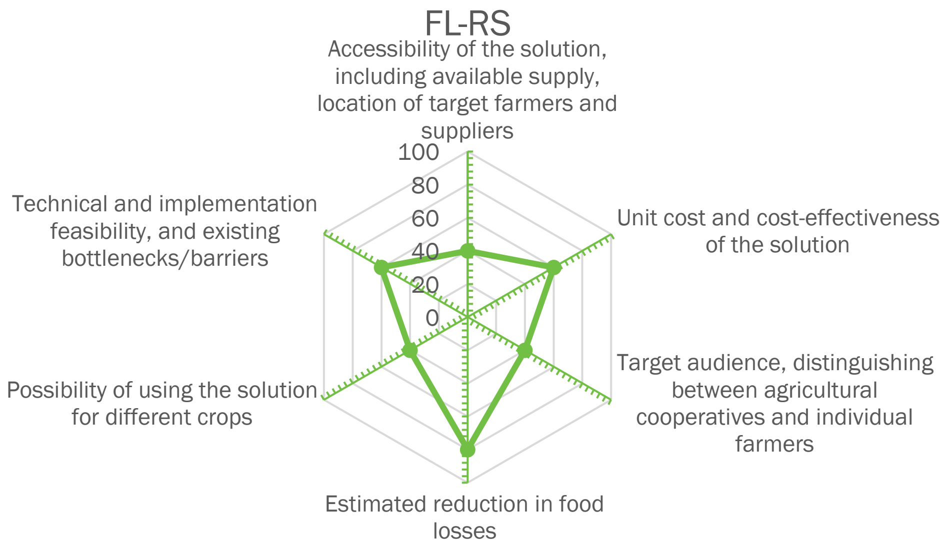


Figure 5-5 - FL-RS evaluation matrix

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 M. &., 2020). For instance, mechanized rice harvesters have been shown to reduce grain loss from the typical 10-15% observed in manual harvesting to as low as 2-5% (Muhammad Yasin, 2019). Similarly, the use of corn harvesters optimizes the timing and condition of harvest, enhancing yields by 20-30% compared to manual methods (Mutungi, 2023).

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

The evaluation of harvesting machinery is provided in Figure 5-6.

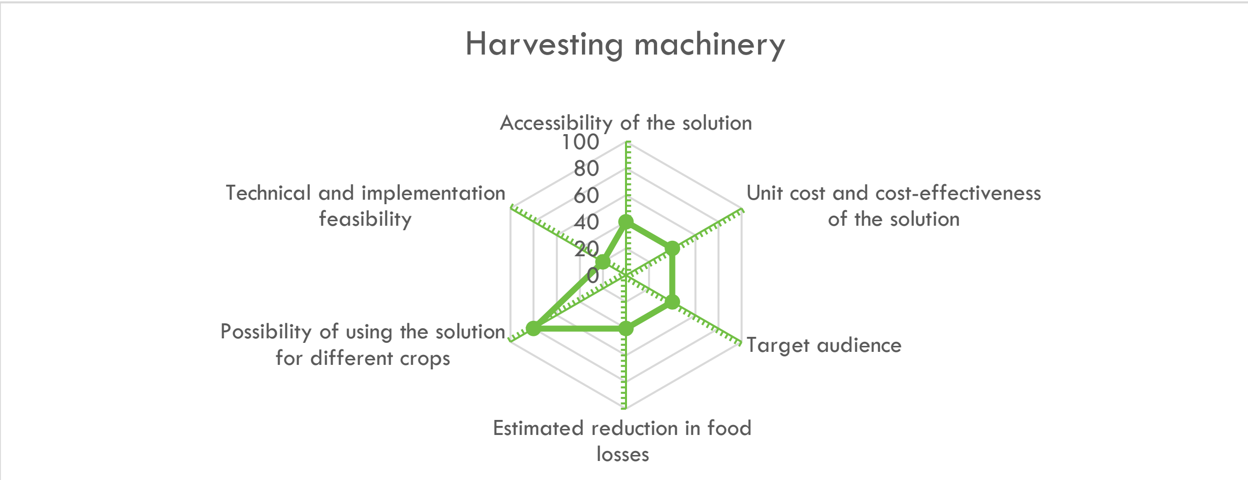


Figure 5-6 - FL-RS evaluation for harvesting machinery

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

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

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

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

The evaluation of mechanical multi-crop threshers and shellers is provided in Figure 5-7.

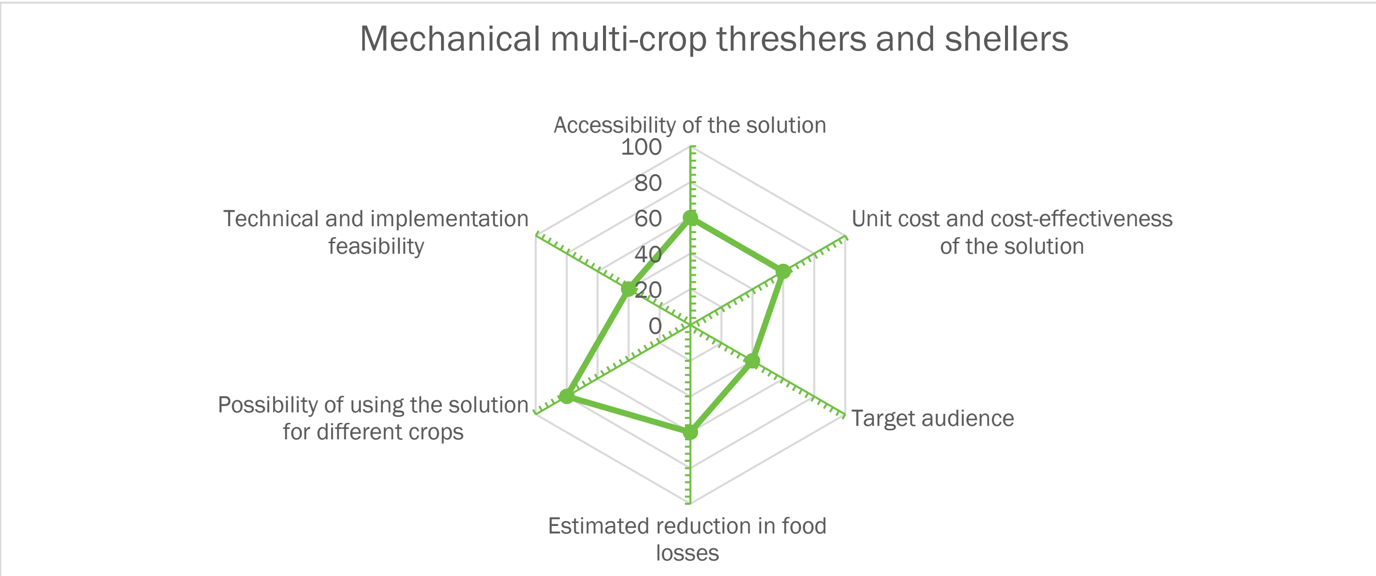


Figure 5-7 - FL-RS evaluation for mechanical multi-crop threshers and shellers

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 R. J., 2011). Legumes and pulses, such as beans and lentils, which traditionally experience losses of 15% to 35%, can see a reduction to 5% to 15% when using improved drying methods with tarpaulins and plastic sheets (Grolleaud, 2002). This is primarily due to better protection from environmental factors and pests.

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

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

The evaluation of tarpaulins and plastic sheets is provided in Figure 5-8.

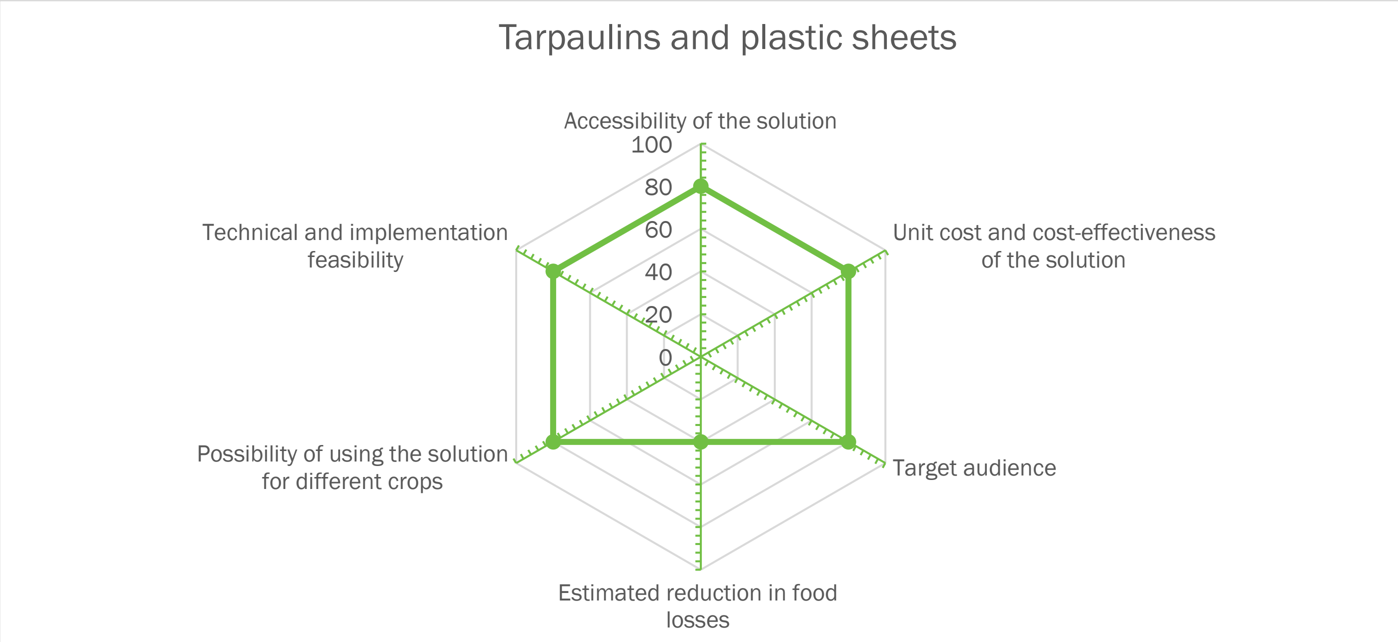


Figure 5-8 - FL-RS evaluation for tarpaulins and plastic sheets

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.

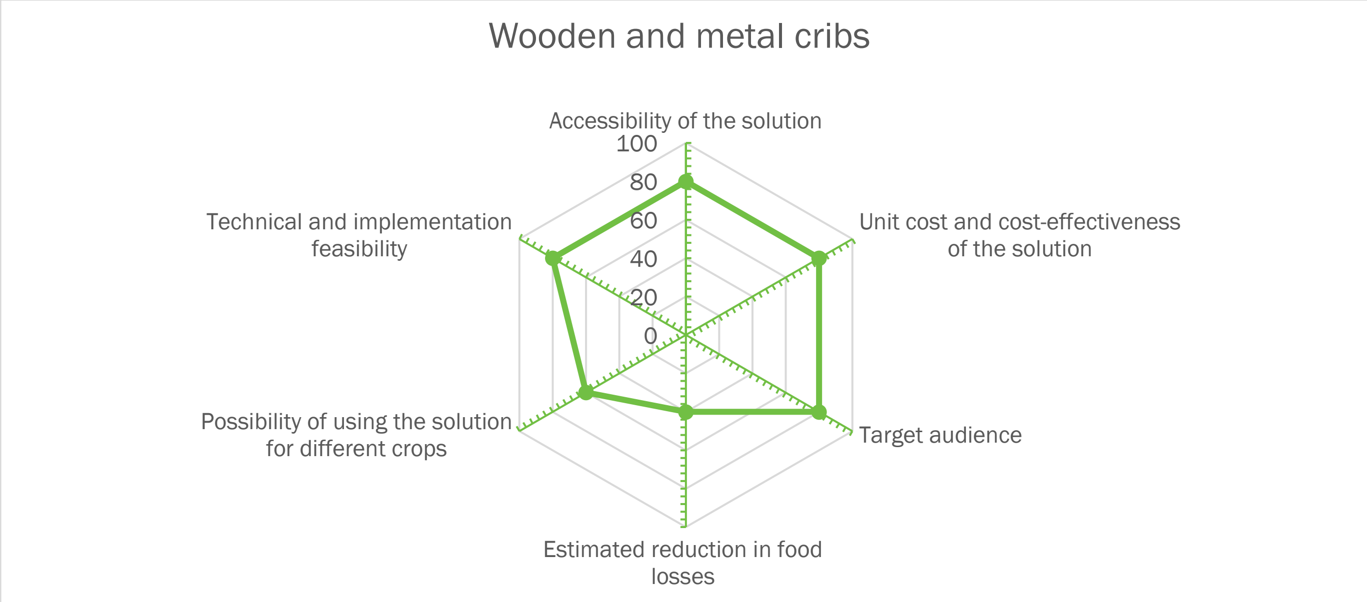


Figure 5-9 - FL-RS evaluation for wooden and metal cribs

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 A. W., 2019). This significant reduction in losses translates to increased food security and economic benefits for farmers, who can store their produce for longer periods without quality degradation.

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

The economic implications of using these improved storage technologies are profound. Case studies have shown that the adoption of metal silos by smallholder farmers can lead to an average increase in annual household income by approximately 20% (Gitonga Z. M., 2015). This increase is attributed not only to the reduction in postharvest losses but also to the ability to sell stored grain when market prices are higher, thereby optimizing income. While the initial investment in metal and plastic silos can be a barrier for some farmers, the long-term benefits in loss reduction and economic gains make them a worthwhile investment (Kuyu C. &., 2022). Moreover, the use of silos contributes to environmental sustainability by reducing the need for chemical preservatives, which are often used in traditional storage methods to combat pests and mould (Kuyu C. &., 2022). The hermetic nature of both metal and plastic silos eliminates the need for such chemicals, thereby promoting safer food practices and reducing environmental contamination.

The evaluation of metal and plastic silos is provided in Figure 5-10.

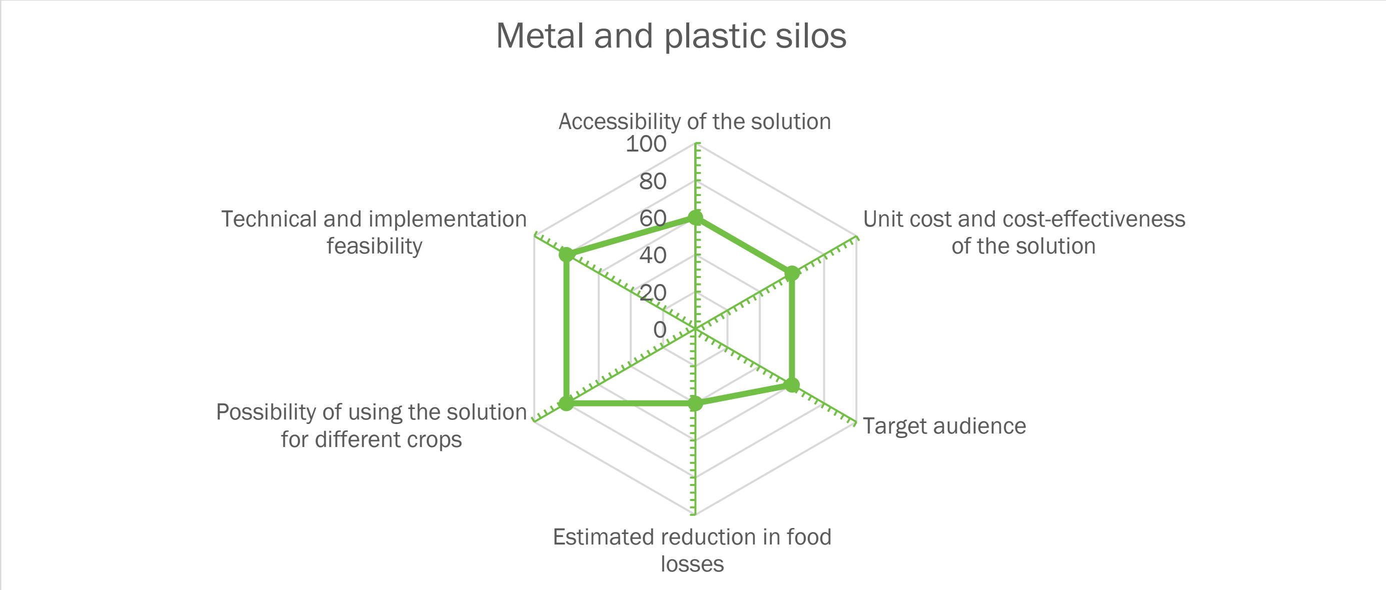


Figure 5-10 - FL-RS evaluation for metal and plastic silos

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 S. M., 2017). Hermetic storage involves airtight conditions that prevent the entry of oxygen, thereby inhibiting the growth of aerobic organisms like fungi and insects. This method has proven particularly effective for staple crops such as maize, cowpeas, and rice, which are prone to significant postharvest losses (Baributsa D. &., 2020). The benefits of hermetic bag storage extend beyond mere loss reduction; they include improved food security, enhanced grain quality, and increased incomes for farmers (Williams S. M., 2017).

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

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

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

The evaluation of hermetic storage bags is provided in Figure 5-11.

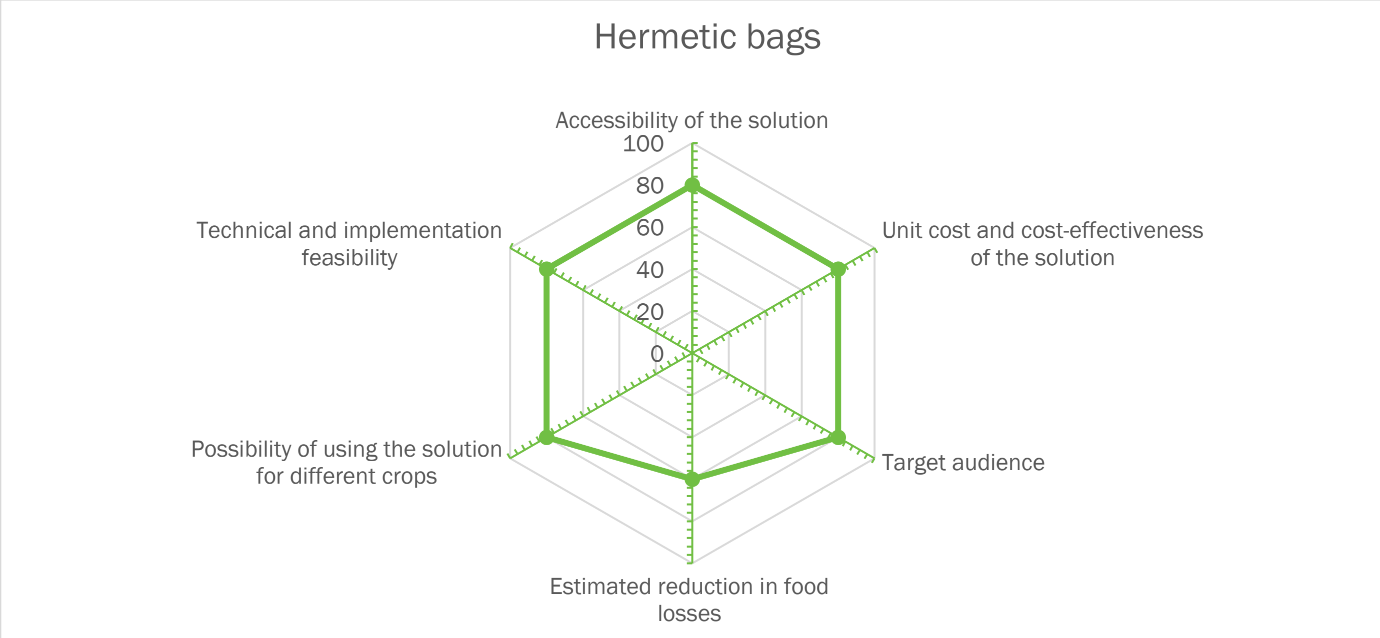


Figure 5-11 - FL-RS evaluation for hermetic bags

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 M. &., 2016). By accurately measuring the moisture content in grains and other produce, farmers can make informed decisions about the timing and conditions of storage, thereby preventing spoilage and degradation. Through minimizing the risks associated with improper storage, moisture meters help ensure that a greater proportion of the harvested produce reaches consumers in optimal condition, supporting the livelihoods of farmers and contributing to the stability of the food supply chain (Hossain M. &., 2016). Studies show that Kenya has already successfully integrated moisture meters into postharvest management practices for grains, particularly maize, resulting in improved storage and reduced losses (Koskei P. &., 2020).

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

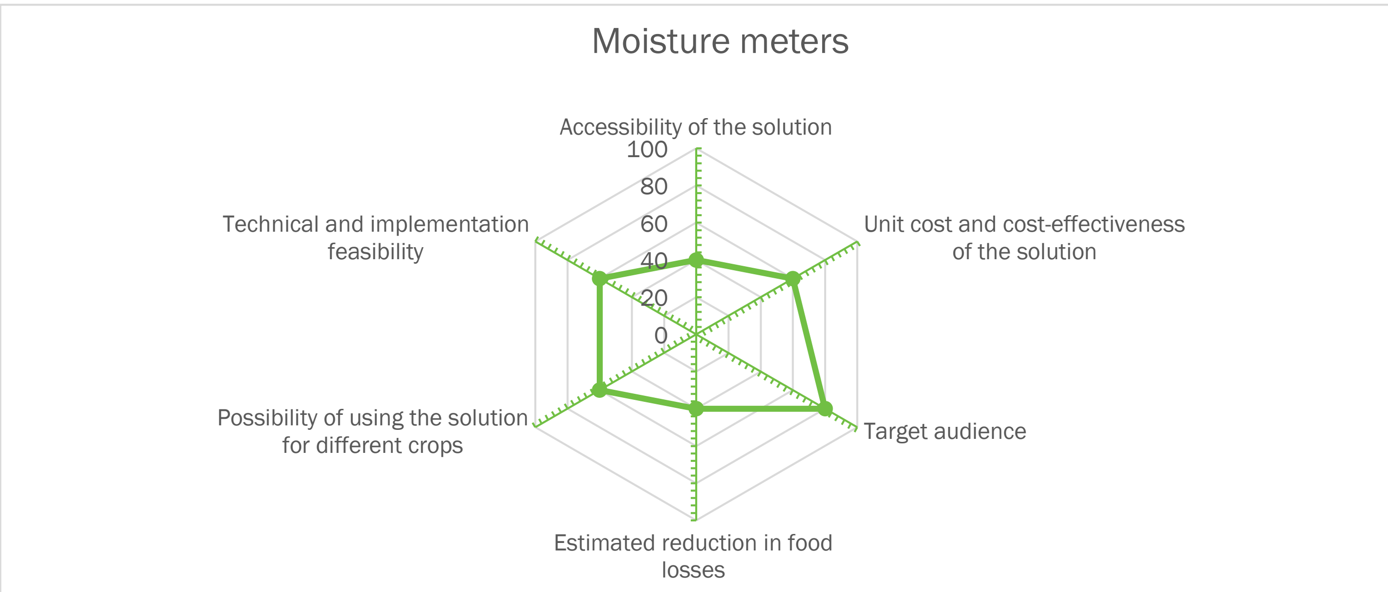


Figure 5-12 - FL-RS evaluation for moisture meters

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 I. &., 2018).

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

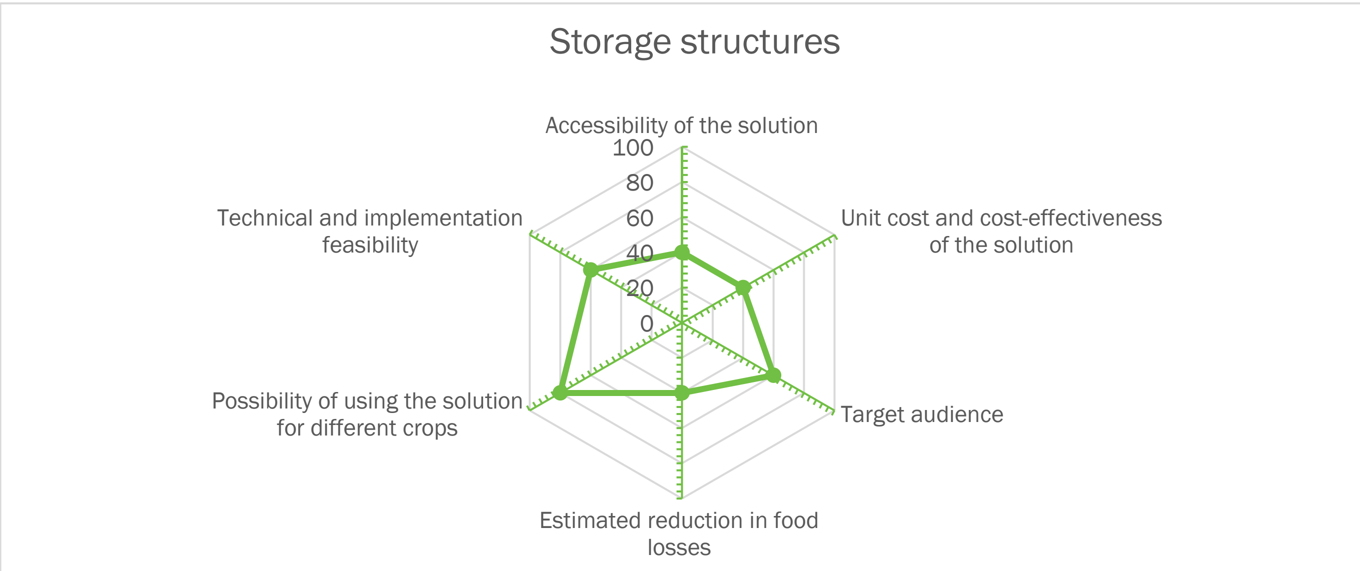


Figure 5-13 - FL-RS evaluation for storage structures

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 T. M., 2011). Pesticides, though controversial due to potential health and environmental impacts, have shown effectiveness in maintaining grain quality (Nukenine, 2010). Research conducted in Ethiopia indicated that the proper use of phosphine fumigation decreased losses in stored wheat by over 40% (Negussie, 2012). As an organic alternative, biological fumigants, including products like Bacillus thuringiensis and diatomaceous earth, provide an eco-friendly approach to pest control, reducing losses by up to 25% in some studies. Plus there remains a considerable need to raise awareness regarding the proper use (dosage and application of chemical protectants) across the countries. Additionally, there is a need to develop the supply of biological protectants and control agents in the markets.

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

The evaluation of storage protectants and control agents is provided in Figure 5-14.

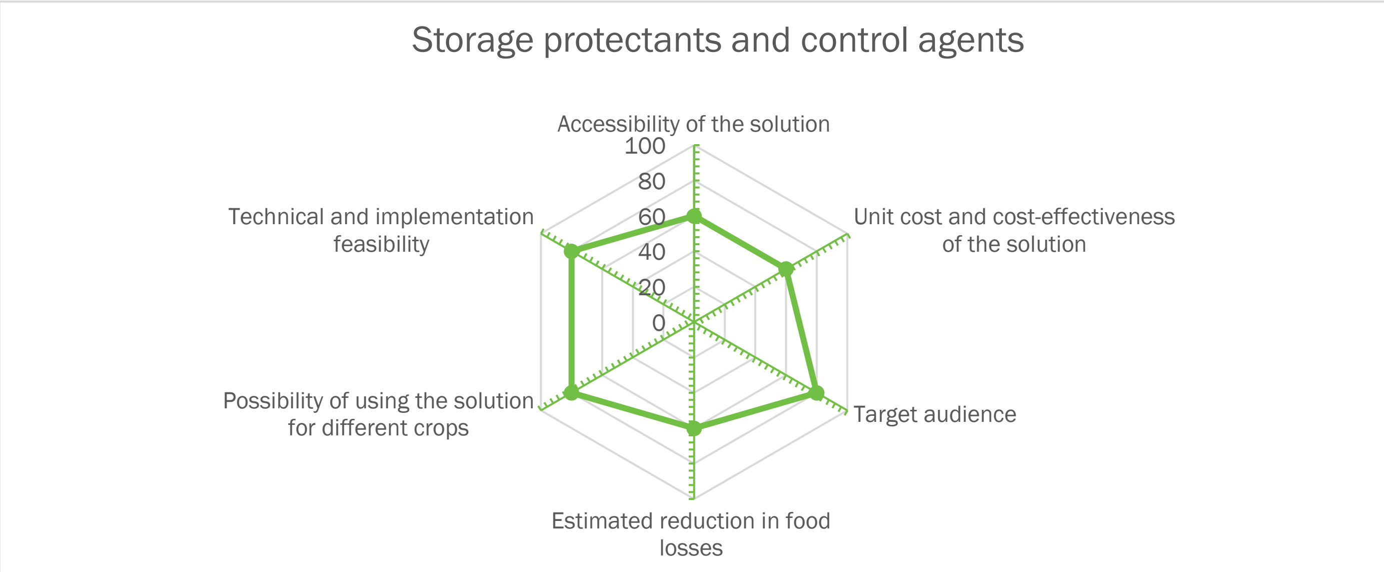


Figure 5-14 - FL-RS evaluation for storage protectants and control agents

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 H. M., 2015). For example, use of improved packaging materials for transporting beans cut postharvest losses by nearly half, from 35% to 18% (Adejumo B. &., 2007). But as identified by (AGRIFIN, 2020), farmers rarely have financial capacity and physical access to transport packaging of suitable quality.

The evaluation of transport packaging is provided in Figure 5-15.

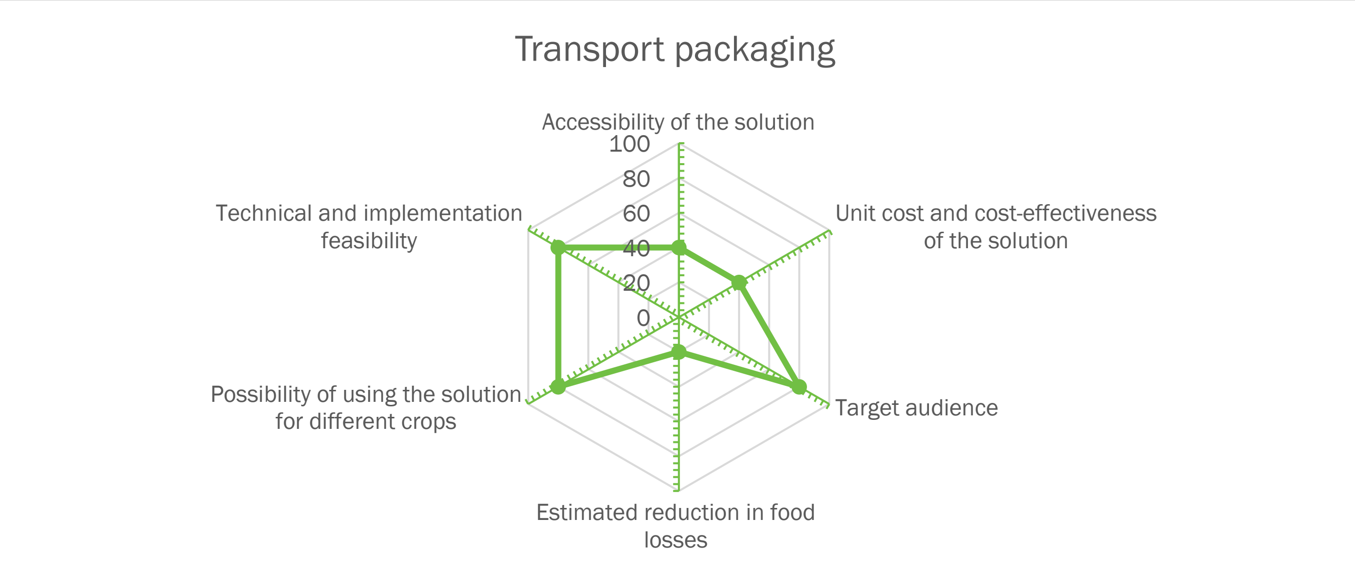


Figure 5-15 - FL-RS evaluation for transport packaging

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

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

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

5.3 DEFINITION OF FEASIBILITY AND PRIORITISATION CRITERIA FOR FL-RS

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

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

- Solutions that can help with food loss reductions and have the potential to be scalable with smallholder farmers
- Solutions that are appropriate to the local context

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

In terms of climate risks, both maize and groundnuts in Malawi are highly vulnerable to extremely hot days, increased average temperatures, and extreme heat/heatwaves, as well as susceptible to increased moisture, caused by the rains and floods (Table 3-10). The erratic nature of rainfall is adversely affecting the productivity of maize and groundnut production in Malawi. Although the total rainfall could be considered as normal, the erratic nature of rainfall sometime results in a dry spell when the maize or groundnuts are at a critical stage when moisture is required. Such conditions negatively impact the overall yield during harvesting, the quality of the crops and noted increase in pests. Unexpected heavy rains during postharvest handling and storage tend to enhance losses due to increased levels of humidity resulting in mould and a decline in the quality of the stored produce. The unpredictability of precipitation also hampers the drying process of crops, resulting in significant post-harvest losses. Sudden heavy rains and flooding affect the transportation of produce from rural areas to the markets due to the poor state of rural roads. Sometimes produce is affected by moisture while in transit if not properly protected. Additionally, heavy rains deteriorate the condition of roads, complicating the transportation of crops to markets. These vulnerabilities emphasize the importance of precise harvesting timing, proper threshing and shelling, and adequate drying and storage facilities.

An evaluation of the ten shortlisted flood resilience solutions (FL-RS) and their potential to mitigate the impacts of key climate hazards in the maize and groundnuts value chains in Malawi is presented in Table 5-6 and Table 5-7 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 5-6 – Evaluation of the potential solutions in addressing key climate hazards in Malawi for maize value chain

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

Table 5-7 - Evaluation of the potential solutions in addressing key climate hazards in Malawi for groundnut value chain

Solutions	Climate hazards			Average rate
	Increased average temperatures, hot days over 35°C, and extreme heat and heatwaves	Heavy rains (large 1-day rains and large 5-day rains)	River and/or urban floods	
Harvesting machinery	4	2	1	2.33
Mechanical multi-crop threshers and shellers	4	4	4	4.00
Tarpaulins and plastic sheets	4	2	2	2.67

Wooden and metal cribs	2	2	2	2.00
Metal and plastic silos	4	5	4	4.33
Hermetic bags	4	4	4	4.00
Moisture meters	3	3	2	2.67
Storage structures	4	4	4	4.00
Storage protectants /control agents	4	2	2	2.67
Transport packaging	3	1	1	1.67

Based on the Table 5-6 and Table 5-7, the FL-RS with the highest average scoring for Malawi are the following, presented in the order of importance:

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

Baseline research findings described in subchapter 5.1 have identified harvesting, drying, threshing and storage for maize (Table 5-2), and drying, stripping, shelling and on-farm storage for groundnuts (Table 5-3) as critical loss factors. As confirmed by stakeholder engagements in Malawi, ensuring proper drying and storage is critical for maize, and proper shelling and storage – for groundnuts. Considering the key climate hazards in the context of Malawi, those FL-RS also need to address the issue of rising temperatures. It is crucial to consider storage solutions that are resistant to overheating and provide protection from moisture due to rainfall. This is especially important given that pest and rodent infestations significantly contribute to postharvest losses in the maize and groundnut value chains, which are often worsened by heat and insufficient storage facilities and techniques. To address this, it is essential to ensure the availability of durable, well-ventilated, and dry storage facilities. Effective storage solutions should include both on-farm and communal options to adequately safeguard the crops.

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

In terms of solutions that would be accessible and scalable for smallholder farmers, factors such as affordability, durability and availability of those FL-RS were considered. Access to finance was named a major barrier that affects smallholder farmers to afford appropriate postharvest loss reduction solutions, during both rounds of stakeholder engagements in Malawi.

Average estimations of prices for all 10 types of FL-RS in Malawi are presented in the Table 5-8 below. For the evaluation, the scoring approach was employed, using the following grade: very high price (1 points), high price (2 points), moderate price (3 points), low price (4 points) and very low price (5 points).

Table 5-8 – Estimation of the costs of top 10 FL-RS in Malawi

Solutions	Estimated cost of the solution in Malawian Kwacha	Estimated cost of the solution in US dollars	Scoring
Harvesting machinery	n/a	n/a	1
Mechanical multi-crop threshers and shellers	Est. 49 500	Est. 3 200 – 3 600	2
Storage structures (e.g., huts, baskets, grain sheds)	n/a	Est. 30 - 500	3

Moisture meters	n/a	Est. 100-300	3
Metal and plastic silos	n/a	Est. 50 - 200	3
Wooden and metal cribs	n/a	Est. 20 - 80	3
Tarpaulins and plastic sheets	35 000	Est. 15 – 30 (0.35 – 2.88 USD per m^2)	4
Transport packaging	n/a	Est. 2 - 20	4
Storage protectants and control agents	n/a	Est. 2 - 16	4
Hermetic bags	3 250 – 4 650	Est. 1 - 4	5

Source: (TractorProvider Malawi, 2024)

While affordability and availability of the solutions will be addressed by the RE-GAIN Programme as part of Component 3 and Component 2 activities respectively, the importance of FL-RS durability remains high. Smallholder farmers generally require low-technology, familiar solutions that are relatively easy to acquire and maintain. However as highlighted during the stakeholder engagement in Malawi, they frequently lack the specific knowledge and capacity to utilize these solutions effectively. This challenge will be supported by capacity-building and awareness-raising activities under Component 1 of the RE-GAIN Programme in Malawi.

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 Malawi include the limited financial capacity of smallholder farmers to invest in mechanized high-tech solutions, coupled with restricted access to credit and bank loans. Additionally, quality low-technology solutions are scarce for harvesting, threshing/shelling, drying, and storing maize and groundnuts 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 Malawi during the baseline assessments (Chapters 3 and 4), and the first round of stakeholder engagement on national and local levels, major losses in both maize and groundnut value chains are observed on the harvesting, and post-harvest handling and storage stages.

During the first round of stakeholder consultations in Malawi conducted in June 2024, each group of participants of local and national workshops shortlisted the top three solutions, that would be relevant for both maize and groundnut 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 5-9.

Table 5-9 – Top solutions for maize and groundnut production, resilience against climate risks, and impact potential for smallholder farmers in Malawi

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

As we can see from the table, the most important solutions include harvesting machinery, storage structures, tarpaulins and plastic sheets. For the final evaluation provided in the Table 5-10, 1 point was given for a single mention of the solution. Solutions that were not included, scored 0 points.

5.3.4 Final evaluation

Taking into consideration all the above-mentioned factors, and considering the major climate risks for Malawi specified in the previous chapters, the physical FL-RS for maize and groundnuts in Malawi with the highest potential to reduce postharvest food losses are highlighted in the Table 5-10 below:

Table 5-10 – Final evaluation of the shortlisted physical FL-RS in Malawi

Solutions	Climate risks		Costs of the solutions	Best solutions in the local context	Final score
	Maize	Groundnut			
Harvesting machinery	2.33	2.33	1	4	9.67
Mechanical multi-crop threshers and shellers	4.00	4.00	2	1	11.00
Tarpaulins and plastic sheets	2.67	2.67	4	3	12.33
Wooden and metal cribs	2.67	2.00	3	0	7.67
Metal and plastic silos	4.33	4.33	3	1	12.67
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	2	11.33
Transport packaging	2.00	1.67	4	1	8.67

Detailed evaluation of their advantages, disadvantages, and existing barriers for 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 Malawi, each out of shortlisted physical solutions were evaluated, including key strategic points such as the advantages and disadvantages of each solution, and key barriers for their use particularly in the context of smallholder farmers. The results of the evaluation are provided in Table 5-10.

Table 5-11 – Results of the shortlisted FL-RS evaluation in Malawi

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	Effective tools that save time and labour, simplifying the post-harvest process. They are easy to use and enhance efficiency in farming operations	The high cost of these machines, both for procurement and maintenance, can be prohibitive	The initial cost of purchase and ongoing maintenance expenses, which can be challenging for smallholder farmers	Numerous stakeholders emphasized their awareness of the benefits of utilizing machinery in harvesting and post-harvest processing to minimize losses and enhance productivity. However, access to finance remains the main limiting factor in improved harvesting and postharvest mechanisation in Malawi
Tarpaulins and plastic sheets	Affordable solutions are used for drying crops and protecting them from the elements. They offer versatility in their application	Materials used for their production are not durable and have a limited lifetime, making them less reliable for long-term use	Short lifespan and the difficulty in accessing these materials consistently	Farmers in Malawi frequently dry their crops on open ground or mats, a practice that can lead to significant wastage. To mitigate these losses, the use of plastic sheeting or tarpaulins would be crucial
Metal and plastic silos	Effective storage solutions that protect produce from pests and environmental factors. They are durable and maintain the quality of stored grains	The cost is high, and they are vulnerable to theft. Additional challenges include the need for skills to construct them and the requirement to monitor temperature and moisture levels	The high expense for smallholder farmers, the necessity for technical skills, and ongoing monitoring requirements	Traditionally, maize and groundnuts in Malawi have been stored in structures constructed from conventional materials or improved silos. However, due to the risk of theft, many farmers currently prefer to store their crops in hessian bags
Storage structures	Help maintain the quality of produce and are adaptable to various	Prone to theft and other security issues and can be costly to sustain	High cost of construction and maintenance and the	

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
	weather conditions. They are suitable for different scales of farming operations		scarcity of materials required for building these structures	
Hermetic bags	User-friendly, chemical-free, and recyclable, significantly extending the shelf life of produce. They provide a safe storage solution that preserves the quality of crops	Are often expensive for smallholder farmers when buying bags for the big household	Affordability of the bags and access to financing to support their purchase	Consulted stakeholders recommended the use of hermetic bags to prevent pest damage, particularly from weevils
Moisture meters	Effective, durable. Allows to check the moisture of the crops before and during storage to prevent aflatoxin development	Expensive and require technical training to use them properly	High costs for common farmers, limited accessibility, lack of technical knowledge on using them	Stakeholders suggested the implementation of moisture meters or sensors in large storage facilities to monitor conditions and prevent spoilage
Storage protectants and control agents	Effective, affordable, and easy to use. They help in preserving the quality of produce by protecting it from pests	Chemicals used can be hazardous to human health and the environment if applied in a wrong way	Need for personal protective equipment and the knowledge and skills required to use these agents safely	Stakeholders identified a correlation between disease and pest prevalence and climatic conditions, indicating that the use of pesticides might be necessary to safeguard crops

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

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

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

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

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

To further prioritize the list of solutions for each country, a high, medium, and low scoring approach was applied, considering synergies and increased potential impact of the solutions on food loss reduction. The final shortlist of prioritized solutions for each country is presented in Table 5-11:

Table 5-11 – Prioritized physical FL-RS for Malawi

Solutions	Level of priority
Harvesting machinery	low
Mechanical multi-crop threshers and shellers	medium
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

Concerning storage protectants and control agents, stakeholders identified these as affordable and beneficial. However, 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 l protectants and control agents in the markets.

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 of biological origin.

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

Taking into consideration the shortlisted solutions for Malawi, as well as their potential in reducing postharvest losses and existing barriers, Table 5-12 provides a brief overview of the proposed solutions' delivery mechanism for Malawi.

Table 5-12 – Proposed delivery mechanism for shortlisted physical FL-RS in Malawi

Solution	Estimated reduction in PHL, % (Table 5-1)	Barriers to solution implementation	Proposed delivery mechanisms
Mechanical multi-crop threshers and shellers	10-30%	• High initial cost of purchase • Need for technical skills and knowledge about operating those multi-crop threshers and shellers • Maintenance expenses	• 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%	• Short lifespan and the difficulty in accessing these materials consistently	• Improved access to solutions through a subsidy scheme • Training and capacity building on the appropriate use of tarpaulins and plastic sheets

Solution	Estimated reduction in PHL, % (Table 5-1)	Barriers to solution implementation	Proposed delivery mechanisms
Metal and plastic silos	10-50%	• High cost • Need for monitoring and maintenance	• Improved access to solutions through a subsidy scheme • Training and capacity building on the appropriate use and maintenance of silos
Storage structures	Up to 15%	• High cost of construction and maintenance • Scarcity of materials required for building these structures	• Improved access to solutions through a subsidy scheme • Capacity building (training of trainers) on the best practices in using storage structures
Moisture meters	Up to 25%	• High costs for common farmers • Limited accessibility • Lack of technical knowledge on using them	• Improved access to solutions through a subsidy scheme • Capacity building (training of trainers) on the best practices in using moisture meters
Hermetic bags	20-30%	• Affordability/cost of the bags • Limited access to finance	• Improved access to solutions through a subsidy scheme • Training and capacity building on the appropriate use of hermetic bags
Storage protectants and control agents	30-40%	• Need for personal protective equipment • Need for knowledge and skills to use these agents safely	• Improved access to solutions through a subsidy scheme • Capacity building on the right usage and dosage of pesticides, training and awareness raising on alternative biological /organic storage protectants

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 Malawi, 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 5-13:

Table 5-13 Proposed Activities Set and Outputs of the RE-GAIN Programme, aligned with the identified risks, needs and barriers in access to FL-RS

Identified risks, needs and barriers	Activity sets	Outputs
Technical and Operational Challenges • Technical challenges in use of technologies and equipment	**Activity Set 1** • Gender-responsive awareness campaign on the impacts of CC on post-harvest food losses and the availability of FL-RS.	Output 1.1. Smallholder farmers supported to adopt FL-RS

Identified risks, needs and barriers	Activity sets	Outputs
• Susceptibility of crops to weather conditions, pests, and contamination • Limited access to markets for smallholder products • Limited awareness of impact of climate change on harvest and post-harvest crop management • Limited awareness of the use of climate information for decision making Skills and Knowledge Requirements • Limited awareness of impact of climate change on harvest and post-harvest crop management • Limited awareness of the use of climate information for decision making • Need for proper training, knowledge, and technical skills for effective use and maintenance of equipment and post-harvest technologies • Limited awareness and knowledge about proper usage and management of FL-RS Health, Safety, and Environmental Risks • High pollution risks and environmental impacts of certain harvesting technologies • Health and safety concerns associated with the use of chemical products as storage protectants	• 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	
	Activity Set 2 • Facilitate market linkages between institutional markets & other buyers & smallholders, Support to structuring of value chains & coordination between market actors	Output 1.2. Improved market linkages between agri-value chain actors
Cost and Economic Constraints • High initial costs and ongoing maintenance expenses of machinery and technologies • Affordability challenges, especially for vulnerable communities • Lack of capital and limited access to finance • Inaccessibility of fuel and high fuel costs in some areas, high energy consumption and maintenance requirements of harvesting machinery Market constraints • Lack of available FL-RS, especially in remote and rural areas • Limited accessibility and (perceived) high cost of FL-RS, especially in rural areas • Limited availability of quality materials and resources for production of FL-RS	Activity Set 3 • Provide business development support & market intelligence for FL-RS manufacturers • Capacity and market development for all market actors • Training of new FL-RS providers (MSMEs, cooperatives, incl. women- and youth - led initiatives) • Facilitate access to finance for FL-RS providers through innovative de-risking schemes	Output 2.1. Business development support for the improved provision of FL-RS on local markets
	Activity Set 4 • Support inclusion of FL-RS in climate-resilient input packages • Structure prefinancing partnership arrangements that include FL-RS • Facilitate the development and deployment of smart subsidy and catalytic grant models, as well as 'lease-to-own models for FL-RS focussing on women and youth as key beneficiaries.	Output 2.2. Financial mechanisms for smallholders and MSMEs to support the adoption of FL-RS
Quality and Reliability Concerns • Variable quality and limited durability of FL-RS present in the market, affecting their reliability Other concerns • Lack of access to solutions and agricultural finance for women • Limited awareness among farmers about the effectiveness and economic benefits of FL-RS	Activity Set 5 • Support the revision of policies that enable FL-RS investments, including tax exemptions, certification and standards for FL-RS quality • Promote successful FL-RS business models for scaling-up & replication	Output 3.1. Enhanced capacity of national institutions to enable investments in FL-RS

5.7 OVERVIEW OF IMPLEMENTATION ARRANGEMENTS

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

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

5.7.1. Executing Entity (EE)

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

The EE is responsible for:

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

AGRA deploys a diverse set of delivery models to deliver its country and institutional strategy. It offers services through its **expert staff**, placed at headquarters in Nairobi; at the East, Southern and West Africa regional offices; as well as at country offices. AGRA staff work with downstream partners and local organizations to implement **specific components** of a contracted programme area with the aim to improve local organizations' capacity, build institutional capacity and ensure long term ownership and sustainability of its interventions. AGRA provides **Technical Assistance (TA) in the form of short- to medium-term expertise support** (through consultants where needed) embedded within or seconded to mandated national, regional and continental institutions (e.g., government ministries, regional economic communities) to drive desired change, and in some instances consultants are hired to support specific assignments that require skilled expertise. AGRA is a **convener (brings stakeholders together around a change agenda, e.g., the Africa Food Systems Summit)** facilitating connections and interactions between different actors and stakeholders within the agriculture and food systems sector. AGRA utilizes advocacy and communication as key tools for change. The specific delivery models will be determined at the implementation stage and will depend on each country context.

5.7.2. Responsible Units

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

5.7.3. Programme Governance

Programme Advisory Group:

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

Programme Implementation Unit

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

- *Programme Management Unit*
  The Programme will establish a management unit that will be functional for the entire duration and be responsible for day-to-day implementation of the project. The PMU will offer overall management, implementation and general technical direction of the entire programme, ensuring an integrated vision among different components. The PMU will consist of five full time positions: i) PMU Lead; ii) Senior Finance Officer; iii) Procurement Officer; iv) Project Analyst; and v) M&E Officer. The PMU will be based in AGRA Nairobi Headquarters, with in-country support from responsible units in the country offices.
- *Technical Expert Group*
  The TEG, also situated within the Nairobi Headquarters, will provide expertise to assist the PMU in the technical implementation of the RE-GAIN programme. The TEG will include several full-time positions, including: i) Program Officer — Gender, Youth and Inclusion; ii) Technical Advisor — Inclusive Finance and BDS; iii) Technical Advisor — Extension and Value Chain Development. These full-time roles will be supported by several part-time technical team members, including: i) Technical Advisor — Inclusive Markets and Finance; ii) Lead — Sustainable Farming, Distribution and Youth in Extension; iii) Technical Advisor — Livelihood Resilience and Climate Adaption; iv) Head: M&E; and v) Technical Advisor — Food Loss Reduction Analytics.

Country-level Implementation Units

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

[3] Vice presidents, relevant business line or programme directors/heads, Lead of PMU , Head of MEL
[4] Which fall under the same legal entity as the PSAA Applicant

Programme Steering Committee

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

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

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

Table 5-14: Country PSC Representatives

Country	PSC Representatives

Malawi	• NDA – Director of Environmental Affairs
	• PS Agriculture represented by
	    • Director of Crop Development Department
	    • Director of Agriculture Extension Services
	• CEO of Farmers Union of Malawi (FUM) or National Association of Farmers (NASFAM)
	• UNDP or Representative of the Donor Committee on Environment.
	• CASANET

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.

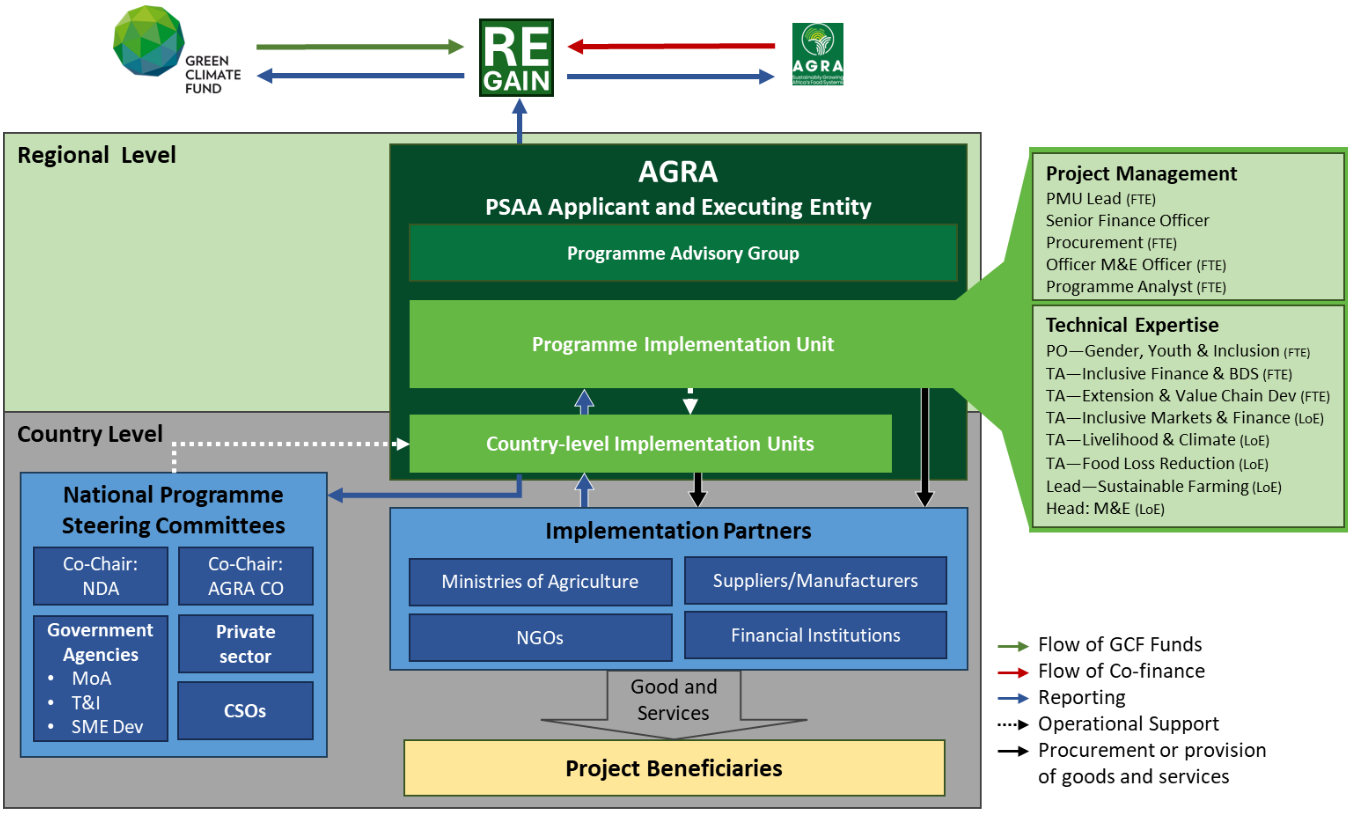


Figure 5-16 Implementation Arrangements for the RE-GAIN Programme

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 AND SUPPLY OF THE PRIORITISED FL-RS

The demand and supply of agricultural machinery and other post-harvest food loss reduction technologies among smallholder farmers in Malawi 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 Malawi, including:

a) Lack of information and awareness about the importance of food losses and available postharvest technologies.

b) Lack of appropriate knowledge and skills within the farming community that hinders the adoption of modern agricultural techniques and more efficient resources management.

c) Low literacy levels among women farmers which hinders their full participation in awareness and training activities, inhibiting their adopting improved agricultural activities, including FL-RS.

d) High cost of some of the FL-RS, such as threshes/shellers, silos, moisture meters and even hermitic bags making them unaffordable.

e) Poor market linkages and market and product information asymmetries which hamper farmers' ability to connect effectively with suppliers.

f) Limited supply of affordable finance due to high interest rates, short loan periods, or lack of access to collateral, limits farmer’s access to loans for investing in FL-RS.

g) Unstable market prices add another layer of uncertainty, making it difficult for farmers to plan and invest in their operations confidently.

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

6.1.1 Demand for specific FL-RS

Mechanical multi-crop threshers and shellers in Malawi are in moderate demand among smallholder farmers, driven by several key factors, primarily revolving around the efficiency gains and economic benefits they offer. The demand is likely to grow as awareness of their benefits spreads and as more farmers seek to improve their productivity and profitability through mechanization. Yet, supply is constrained by the high cost of equipment and limited local manufacturing.

The demand for **tarpaulins and plastic sheets** in Malawi's agricultural sector is both significant and growing, driven by their crucial roles in enhancing productivity and protecting crops. Tarpaulins are extensively used by farmers to shield crops from adverse weather conditions, such as heavy rains and intense sunlight. This protection is particularly important during the harvest period to prevent crop losses. Additionally, tarpaulins are used to cover harvested crops during drying and storage, reducing the risk of spoilage and contamination, which is essential for maintaining the quality of crops like maize, soybeans, and groundnuts before they are processed or sold. While the supply chain is robust, affordability remains an issue, especially considering the recent price fluctuations, and high-quality, affordable products are often in short supply.

The demand for **hermetic bags** in Malawi's agricultural sector is increasing due to their effectiveness in reducing post-harvest losses and protecting stored grains from pests, moisture, and mold. Hermetic bags create a sealed environment that significantly limits the oxygen available to pests, preventing their multiplication and reducing the need for chemical pesticides. Research indicates a growing willingness among Malawian farmers to invest in hermetic bags due to their proven benefits. Demonstration projects and awareness campaigns have helped increase the adoption rates. Farmers who have experienced the advantages of hermetic storage firsthand are more likely to continue using and recommending these bags. But the higher cost of hermetic bags remains a barrier for widespread adoption among smallholder farmers. There are also cases of cheap bags sold as high-quality hermetic ones, that fail to protect crops, and therefore put future investments into them at risk. Therefore, continued education and promotion are necessary to increase awareness of the benefits of hermetic storage. This includes demonstrating the economic benefits and long-term savings associated with reduced grain losses.

Metal and plastic silos are only in moderate demand for their effectiveness in reducing post-harvest losses, due to their high costs and the need for proper installation and ongoing maintenance. In addition, the high production costs limit their supply.

Moisture meters have low but growing demand as farmers become more aware of their use in preventing spoilage. Most devices are imported, and supply is constrained by high costs and limited distribution. There is a need for farmer training to promote their 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, making them inaccessible to smallholder farmers who often rely on less effective traditional structures.

6.2 MARKET OF SUPPLIERS AND MANUFACTURERS OF FL-RS

On the supply side of FL-RS, agricultural sector in Malawi 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 Malawi, 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, SARO Agro Industrial Ltd, Farming and engineering Services (FES), and Tractors Malawi, among others, provide agricultural machinery solutions such as **mechanical multi-crop threshers and shellers**, tractors and harvesting machinery. They mainly import the threshers, and then distribute their products across the country through a network of dealers and agricultural machinery suppliers. The estimated supply capacity varies depending on the company. Specific information about major country suppliers of FL-RS including their capacities, main solutions produced/supplied, and whether those solutions are locally produced or imported, together with the average costs of solutions, is provided in the Appendix 9.

Among the prioritised FL-RS, **tarpaulins and plastic sheets** are commonly available in Malawi. They are mostly produced locally by companies such as Polypack, Lilongwe Plastic Packaging Limited, Delhi Tripal House, and others, and sold by agricultural dealers directly to the farmers.

Hermetic bags are among the most popular primary physical solutions in Malawi. Leading importers in this sector are Farmers World, AGORA, PICS Malawi, Agro Input Suppliers Limited, among others. The bags then being distributed and sold through local vendors.

Metal and plastic silos in Malawi are often being locally produced, by the big companies such as Agro Input Suppliers Limited and others.

Moisture meters in Malawi are primarily imported by companies such as Good Hope Pharmaceuticals among others, which also provide distribution services throughout the country, often partnering with agrodealers and other third-party distributors to reach a wide range of customers in both urban and rural areas.

Improved communal **storage structures**, such as communal grain sheds, are being either produced in the country, or imported as prefabricated items (primarily from China) and assembled locally. Few private sector companies offer these kind of storage structures for sale. Those companies include Sakuwa Steel Limited, and LASEC Group.

As for the **storage protectants and control agents**, companies such as Farmers Organisation Limited, Osho Chemicals Limited, Rentokil and Fumigation International Malawi and others import those from other countries. Their headquarters/ main office are primarily located in Lilongwe and other nig cities, and they work with a network of agrodealers for the distribution of solutions in different areas of the country.

6.3 ACCESS TO FINANCE

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

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

6.3.1 Barriers to access

6.3.1.1 Smallholder farmers barriers to FL-RS adoption

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

6.3.1.2 Agricultural MSMEs barriers to FL-RS adoption

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

6.3.1.3 Financial Institutions' barriers to supply agricultural solutions

Financial institutions consider the agricultural sector as high-risk, due to the inherently unpredictable nature of agricultural profitability, influenced by factors like weather and market volatility. The high risk and cost of the agricultural sector, results in banks charging high interest rates over short tenors, which put financial products beyond the reach of Agricultural MSMEs or add to their existing financial burdens. There is a notable lack of financial products tailored to the unique needs of agricultural value chains, which should ideally account for seasonality, climate risk, and the extended lead times between production, off-taking and selling to end consumers.

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

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 Malawi. 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:

6.3.3 Overview of key financing products that currently serve farmers in Malawi

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

In Malawi, four recent financial support interventions have been identified to assist agricultural development:

1. **Government Input Subsidy Programme:** This initiative provides selected impoverished farming households with coupons to purchase agricultural inputs, at subsidized prices.
2. **Agriculture Commercialisation Programme (AGCOM):** This programme collaborates with registered agricultural cooperatives, offering matching grants based on approved business plans. It supports both farming and agro-processing activities.
3. **Agriculture Commodity Exchange (ACE):** ACE facilitates grants to farmer cooperatives for purchasing storage facilities and acquiring market information, such as commodity prices.

4. **Support from Non-State Actors:** Various projects are supported by non-governmental organizations (NGOs) and coordinated through local agencies, adhering to agreed-upon operational guidelines to benefit selected households.

Government Input Subsidy Programme: This programme allows small farming households to acquire agricultural inputs at reduced prices. For instance, in the context of FL-RS, subsidized pesticides are popular among farmers due to their immediate effectiveness in protecting crops from pests. However, challenges include limited availability and expiry of pesticides, budget constraints, and restrictive selection criteria that prevent some deserving households from accessing these subsidies. As an alternative solution, reducing taxes on shelling equipment to make it more affordable for farmers could be very effective in Malawi.

Agriculture Commercialisation Programme (AGCOM): AGCOM provides matching grants to agricultural cooperatives. To qualify, cooperatives must submit strong project proposals and raise 30% of the matching grant. Farm equipment, such as shellers, could be funded through this programme, enabling farmers to handle and process their commodities more efficiently.

Agriculture Commodity Exchange (ACE): ACE grants aid farmer cooperatives in acquiring storage facilities and market information. This support enhances farmers' ability to store produce, reduce postharvest losses, and access market data.

Support from Non-State Actors: Organizations such as the Food and Agriculture Organization (FAO) and Feed the Future sponsor various projects through NGOs. These initiatives help reduce food losses, lower pesticide costs, increase access to shelling equipment and storage facilities, and improve market access through aggregation and bulking facilitated by ACE's storage programs.

Overall, these financial support interventions collectively aim to bolster agricultural productivity, reduce postharvest losses, and enhance market accessibility for Malawian farmers.

6.3.4 Suppliers of financial products and services

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

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

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

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

Financial partner	Comment
Standard Bank Malawi	Standard Bank offers loans to farmer cooperatives. These loans feature favorable interest rates and repayment schedules aligned with farmers' cash flows. The partnership aims to improve financial literacy and credit history among farmers, increasing their productivity and market access
National Bank of Malawi	The bank offers the Farm Infrastructure and Implements Loan, financing eligible farmers for acquiring agricultural equipment such as irrigation systems, tractors, and processing equipment. This loan targets both small-scale and commercial farmers to boost agricultural productivity
Malawi Agriculture and Industrial Investment Corporation (MAIIC)	The establishment of MAIIC is a ground-breaking partnership between Government, the private sector and international investors to play a leading role as a catalyst for socio-economic development, job and wealth creation in Malawi. Operating as a sustainable and commercially driven entity, MAIIC has an independent board of directors, the majority of whom are from the private sector. GoM shareholding in the institution is limited at 20 percent. MAIIC has LoI with AGRA, and interested in participation

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 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 conditional procurement for smallholder farmers to reduce the cost of hermetic technology and drying sheets and smart grants to reduce the cost and risk of providing loans to Agricultural MSME buying FL-R equipment and storage solutions.

6.4.1 Solutions for smallholder farmers (part of activity 2.2.1)

Model 1 encourages the local provision of FL-RS interventions by employing conditional procurements to subsidize interventions at the smallholder farmer level, termed 'smart-subsidies.' Essentially, this model allows agro-dealers to offer FL-RS to smallholder farmers at a lower cost by using GCF funds to purchase one item for every two items bought and sold by an agro-dealer, passing the subsidy as a discount on the purchase price to the smallholder farmers:

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

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

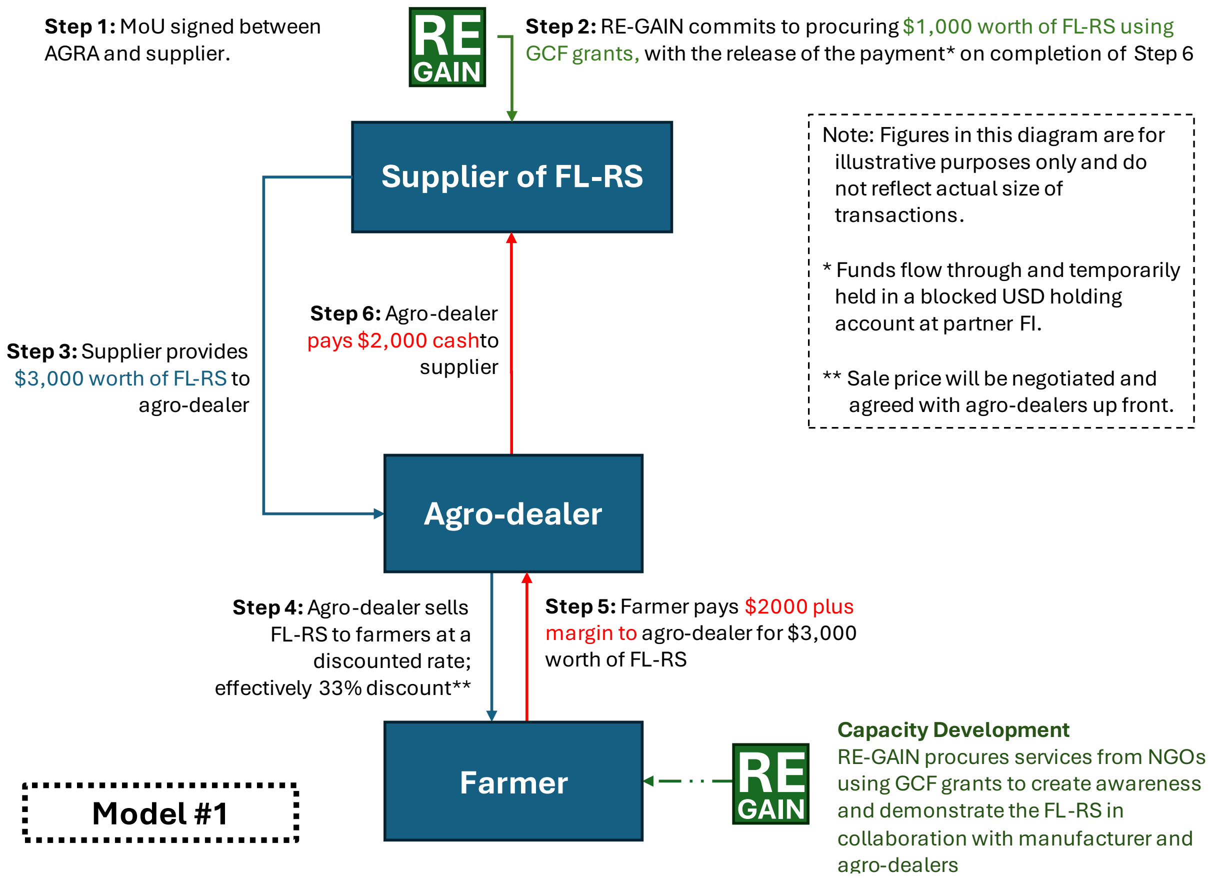


Figure 6-1 Model 1 for RE-GAIN Programme

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 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 high 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

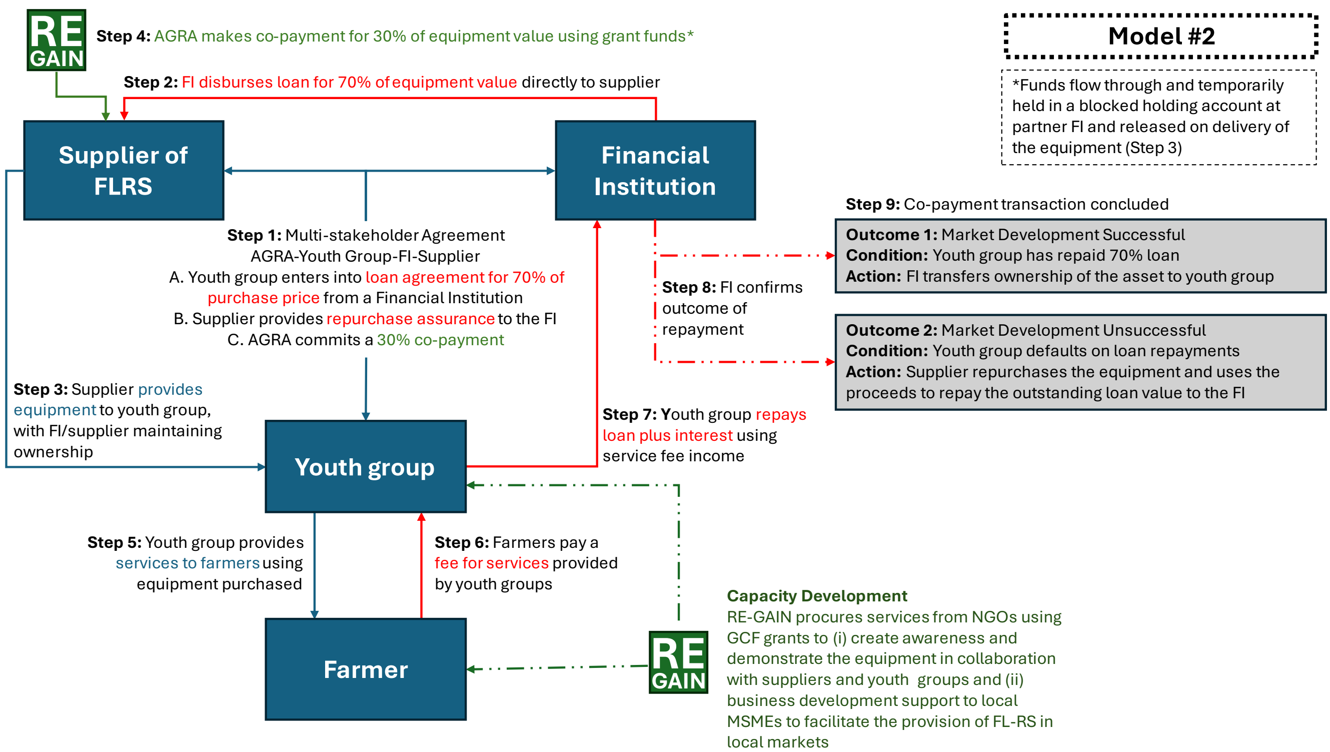


Figure 6-2, with detailed descriptions of each step in the following text. While RE-GAIN will facilitate the establishment of the entire process, its active involvement beyond Step 4, with ownership of Steps 5-9 transitioning to the three partners: youth groups, suppliers, and financial institutionswho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

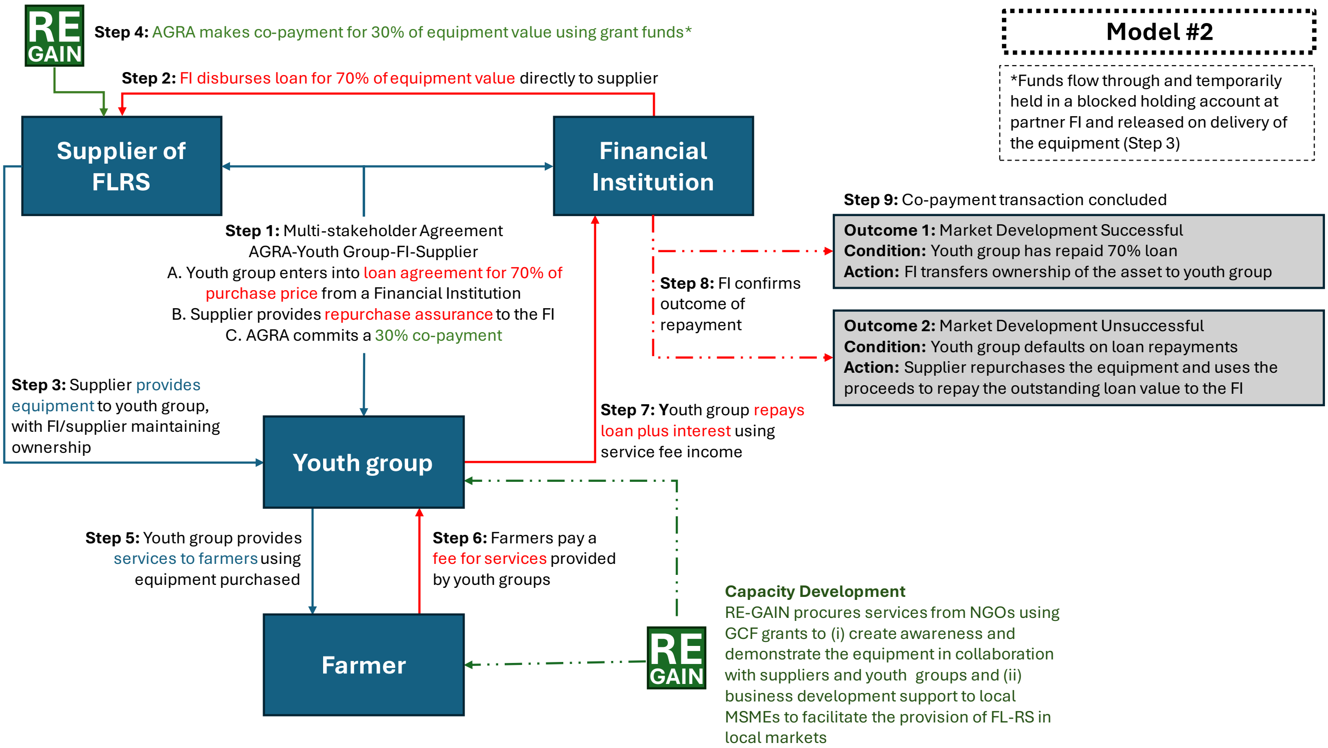


Figure 6-2 Model 2 for RE-GAIN programme

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 account in AGRA's name at no/low cost and interest rate offered on the AGRA deposit
- Preferable presence (branch or agents) in the regions where the programme will be implemented

6.4.2.3 Eligibility criteria for Youth Groups, MSMEs and Cooperative

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

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

6.5 MARKET OF PROVIDERS FOR AWARENESS RAISING AND CAPACITY BUILDING

Awareness raising and capacity building covered by the Component 1 or RE-GAIN Programme requires experienced partners in awareness campaigns and smallholder training. AGRA has historically worked in Malawi 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 Malawi. To have maximum impact in Malawi, the awareness campaign should use mass media, such as TV, radio and social media. Key messages are to be formulated, media to be developed and then disseminated thought the different platforms.

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.

The list of potential implementation partners fir the awareness and capacity building activities in Malawi is provided in Table 6-2.

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

Organization	Description
Farmers Union of Malawi (FUM)	Established in 2003, FUM is an umbrella organization for various farmers' groups in Malawi. Its objective is to enable farmers to participate in the design, implementation, and evaluation of policies and programs aimed at improving their livelihoods
National Association of Small Farmers of Malawi (NASFAM)	NASFAM focuses on promoting the interests of smallholder farmers, providing them with resources, and supporting agricultural development
Association Of Women in Agriculture Malawi (AWAK)	AWAK empowers women in agriculture by providing training, financial inclusion, market linkages, and support for climate-smart agriculture. The organization aims to enhance food security and nutrition, advocate for climate justice, and promote economic empowerment for women farmers. AWAK's programs also focus on value addition and creating sustainable agricultural practices

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

6.5.1 Eligibility Criteria for Extension Services Recipients

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

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

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

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

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

- Legal capacity to operate: Registration (and ability to produce registration certificate) as a sole trader, partnership, franchise, cooperative, or limited liability company in good order with the local tax authorities;
- If operating as an importer, evidence of compliance with import permits;
- If appropriate, demonstrated compliance with any Environmental standards or requirements to obtain licences or environmental impact assessments, reports or management plans as required by local laws;
- Proof of VAT registration;
- Preferably a track record of stocking and selling FL-RS as defined as part of the RE-GAIN programme preferably of the selected manufacturer or importer;
- Evidence of record keeping, including financial 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).

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

The selection process should ensure that the VBA is:

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

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

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

- Legal capacity to operate: Registration (and ability to produce registration certificate) as a sole trader, partnership, franchise, cooperative, or limited liability company in good order with the local tax authorities
- If operating as an importer, evidence of compliance with import permits
- If appropriate, demonstrated compliance with any Environmental standards or requirements to obtain licences or environmental impact assessments, reports or management plans as required by local laws
- Proof of VAT registration
- Preferably a track record of producing and selling FL-RS as defined as part of the RE-GAIN programme that is approved by the national authorities

- Evidence of record keeping, including financial records;Willingness and financial capacity to expand the production levels and distribution network (agrodealers, cooperatives, development projects,) for the FL-RS
- Willingness and financial and human capacity to develop and deploy (subsidized) marketing efforts to enhance uptake of the FL-RS among small scale producers
- Presence in the target regions in the selected countries for the programme;
- Preferably engaging in the provision of solutions for smallholder farmers

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

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

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

6.5.2 Eligibility Criteria for Extension Services Delivery Partners

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

6.5.2.1 Fit for Purpose

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

- Unless specifically stated otherwise in this section, must be registered in the national country with valid registration documents;
- For its stated area of expertise, organization must produce certifications, marks or permits as required by national legislations, demonstrating adherence with relevant codes of practice, industry standards etc
- Organization's primary business activity must be in the stated focal countries;
- Organization must be in a sound financial condition;
- Organization must have sufficient existing capability/capacity to perform as required. AGRA may consider limited funding for capacity building only if the entity's proposal is determined to be of interest to AGRA;
- Organization must have demonstrated favorable past performance record;

- Organization must have accounting systems, procurement practices and corporate integrity/ethics aligned to AGRA systems and values;
- Organization must not have been previously excluded from the eligibility to receive funding from any of AGRA's partners;
- Demonstrate inclusivity and promote sustainability principles in past project activities

6.5.2.2 Technical Competencies

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

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

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

6.5.2.3 Evaluation Criteria/Scoring Weights

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

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

6.6 SUPPORTING AN ENABLING ENVIRONMENT FOR FL RS ADOPTION AND UPTAKE

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

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

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

1. Support domestication of existing Regional Postharvest Loss Management Strategies;
2. Support the development of national strategies, policies, and legislation enabling food loss reduction in line with national agrifood system objectives and policy frameworks;
3. Support the development of programmes and initiatives to improve the availability of accessible weather information;
4. Support the development and implementation of national food loss strategies and action plans, ensuring policy coherence and mutual accountability through multistakeholder, intersectoral and inter-ministerial collaboration and coordination to align visions and interests of all stakeholders and sectors;
5. Support the development of collaboration platforms across industry players and key value chain actors, including academia, research centers and innovation hubs to share knowledge and best practices on food loss reduction;
6. Supporting Public-Private Partnerships, that allow for greater collaborations between the government and private sector to invest in innovative postharvest technologies, modern storage facilities and transportation logistics;
7. Strengthen institutional capacity for effective partnership, cooperation, and engagement of postharvest management stakeholders to facilitate the execution of planned interventions

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

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

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

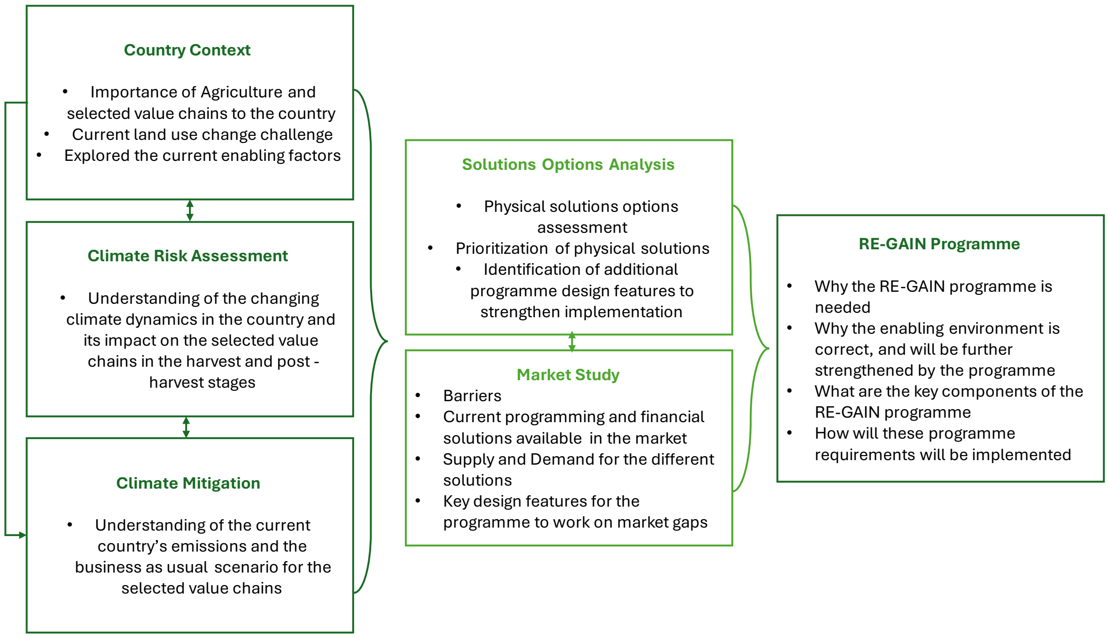


Figure 7-1 Content Summary of Feasibility Study for the RE-GAIN programme

With this in mind, this feasibility study aimed to assess the most viable programme to support smallholder farmers in the harvest and post-harvest stages of the maize and groundnuts value chains within the Malawian 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. Malawi 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 Malawi has a foundational enabling environment for a comprehensive food-loss reduction programme aimed at promoting both the supply and demand of these solutions. However, despite this supportive framework, there is a clear need for a programme like RE-GAIN. Currently, no existing programs specifically focus on simultaneously building climate resilience and addressing harvest and post-harvest food losses. Most initiatives either concentrate solely on enhancing climate resilience in Malawi 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 Malawian 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 Malawi, and highlighted the lack of a unified initiative that can respond to these growing challenges and support Malawi's mitigation initiatives. RE-GAIN offers a solution by reducing food losses across the maize and groundnuts 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 Malawi. Over time, this programme will become self-sustaining, significantly improving the resilience and sustainability of the country's agricultural sector.

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