ANNEX 2

Ethiopia

Teff and Wheat
Version 4

2024

RE-GAIN: Scaling Solutions for Food Loss in Africa

CONTENTS

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ACRONYMS

APHLIS	African Post-harvest Losses Information System
BAU	Business As Usual
CAADP	Comprehensive Africa Agriculture Development Program
CCRA	Climate Change Risk Assessment
CMIP	Coupled Model Intercomparison Project
COVID	Coronavirus Disease
CREW	Climate Resilient Wheat Value Chain Development Project
ENSO	El Nino-Southern Oscillation
EU	European Union
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FL-RS	Food Loss Reduction Solutions
GCF	Green Climate Fund
GDP	Gross Domestic Product
GGW	Great Green Wall
GHG	Greenhouse Gas
GHGI	Greenhouse Gas Inventory
GTP	Growth and Transformation Plan
IFAD	International Fund for Agricultural Development
IGREENFIN	Inclusive Green Financing Initiative
INFORM	Index for Risk Management
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Intertropical Convergence Zone
LUCF	Land Use Change and Forestry
MSMEs	Micro, Small, and Medium Enterprises
NAIP	National Agriculture Investment Plan
NAP	National Adaptation Plan
NDA	National Designated Authority
NDC	Nationally Determined Contributions
OCP	Office Chérifien des Phosphates
OECD	Organisation for Economic Co-operation and Development
PIF	Policy Investment Framework
PSNP	Productive Safety Net Programme
RE-GAIN	Resilience and Food Security Gain Initiative
SCALA	Scaling up Climate Ambition on Land Use and Agriculture
SDG	Sustainable Development Goals
SME	Small and Medium Enterprises
SO	Strategic Objective
SSA	Sub-Saharan Africa
SSP	Shared Socioeconomic Pathways
TAAT	Technologies for African Agricultural Transformation

TNC	The Nature Conservancy
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USD	United States Dollar

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. For Ethiopia, the impact on teff and wheat, two of the country's primary crops, is profound, with **post-harvest losses reaching up to 20% for teff and 30% for wheat** (APHLIS, 2024). These losses have broad social and economic implications due to Ethiopia's reliance on these crops for food security and economic stability. The increasing frequency of droughts and floods in Ethiopia exacerbates food losses, endangering the livelihoods of smallholder farmers and threatening the nation's food supply (World Bank, 2023).

Given the threat of climate change and the significance of agriculture to the economy, management of post-harvest food losses within Ethiopia's agricultural activities and growing seasons, specifically teff and wheat crop production, is necessary to ensure socio-economic stability. Agriculture is the backbone of Ethiopia's economy, supporting livelihoods and contributing 37.6% to the GDP (World Bank, 2023) and employing approximately 75% of the workforce. Smallholder farmers, who manage 95% of the agricultural land, primarily cultivate teff and wheat, among other crops (IGAD, 2018). Teff is a staple crop integral to Ethiopian cuisine, largely used for making injera, a traditional Ethiopian bread. Wheat is a critical cereal crop for Ethiopia, used for various food products, including bread and pasta, and is vital for reducing import dependency and ensuring food security. The country's **agricultural activities are concentrated in the highland and lowland regions, with distinct growing seasons:** the Belg season from February to May, the Kiremt season from mid-June to mid-September, and the Bega season from October to January. 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 (FAO, 2015; Ethiopia, 2022).

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 Ethiopia's Climate Resilient Green Economy Strategy (2011-2025) and the National Adaptation Plan (NAP) (2017). These policies are largely targeted at enhancing agricultural productivity, promoting sustainable practices, and increasing climate resilience. Other programs have been initiated, such as the Resilient Landscapes and Livelihoods Project (FP136) and the Inclusive Green Financing Initiative (IGREENFIN I) (FP183) under the Green Climate Fund (GCF). However, considering the significance of these sectors and the impacts of climate change on post-harvest food losses, Ethiopia'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 Ethiopia's agricultural sector is necessary to determine appropriate climate adaptation measures. Ethiopia faces significant climate risks, including increased temperatures, erratic rainfall, and more frequent droughts and floods. These risks predominantly affect the highland and lowland regions, with central and northern areas being particularly vulnerable. The impacts of these climate risks include reduced crop yields, increased pest infestations, and soil erosion, leading to heightened food insecurity. Over the past decades, these climatic changes have worsened, with temperatures increasing by approximately 1°C from 1960 to 2006, and further significant

increases in recent years. The average mean surface temperature is projected to rise by 0.5°C to 2°C by the 2050s. Additionally, the number of hot days and nights has increased by 20% and 37.5%, respectively. Rainfall has become highly variable, with no statistically significant trends overall, but a 20% decrease in rainfall over the south-central region and increases in the western highlands future (World Bank, 2021). Climate predictions suggest that these trends will be exacerbated in the future.

The prevalence of these climate risks affects necessities the application of adaptation measures to ensure minimisation of post-harvest food losses. For teff, climate variability leads to inconsistent yields and higher post-harvest losses. This is evident with the increased frequency of droughts and the variability of the Belg and Kiremt rainy seasons, particularly from 2013 to 2018. These variations have led to substantial yield reductions, with an observed total yield loss of 25% to 30% total attributed to the combined effects of increased temperature, erratic rainfall, and frequent droughts. Projections indicate that teff yields will continue to be negatively affected under future climate scenarios. By 2050, the suitability for teff production is expected to decrease by 4% under the RCP2.6 scenario and by 7% under the RCP8.5 scenario due to rising temperatures and changing precipitation patterns (The World Bank, 2021). Additionally, post-harvest losses are exacerbated by inadequate drying and pest infestations. The losses will negatively affect national food security, lower yields will result in reduced income for farmers, increased prices due to the imbalance of supply and demand and will require an increased dependence on imports. Managing adaptation measures to stabilise teff yield and reduce post-harvest losses due to drought and variable rainfall is therefore critical for the value chain.

Wheat is similarly impacted by climate change, with droughts and irregular rainfall reducing yields and increasing losses during storage and processing. The severe droughts experienced during the 2015 El Niño event, for example, which caused widespread crop failures and increased post-harvest losses due to poor storage conditions and pest problems. Wheat yields are projected to decrease by 9% under the RCP2.6 scenario and by 12% under the RCP8.5 scenario until 2050 due to climate change impacts such as increased drought exposure and variability in rainfall (World Bank, 2024). The implication of these climate impacts on wheat includes reduced national production, increased dependence on wheat imports, and greater food insecurity for the population. Therefore, climate adaptation measures for growing and processing of wheat are vital to mitigate the negative effects of drought and irregular rainfall on wheat production.

Like adaptation, mitigation efforts are needed to minimise the negative effects of climate change on Ethiopia's agricultural sector. Between 2019 and 2022, the forest land in Ethiopia decreased from 17,141.5 ha to 16,922.5 ha, primarily due to the increase of agricultural land (including arable land) (FAOSTAT, 2022). This shift in land use is significant, as the expansion of agricultural areas has historically occurred at the expense of forested regions, contributing to increased greenhouse gas emissions due to deforestation and land use changes. The trend reflects the country's ongoing struggle to balance agricultural needs with environmental conservation (World Bank, 2023).

This is compounded by Ethiopia's emissions trajectory, with agriculture and land use changes contributing to 80% of the country's greenhouse gas emissions (FAO, 2015; IPCC, 2019)**.** Ethiopia's GHG inventory projects a substantial increase in emissions by 2030 under business-as-usual (BAU) scenarios. Emissions from managed soils, including agricultural soils, are expected to rise to 11 $MtCO_2e$ by 2030. In the land use change and forestry (LUCF) sector, emissions are projected to increase significantly, reaching 140.2 $MtCO_2e$ by 2030 (Fedral Democratic Republic of Ethiopia, 2021). Mitigation of these emissions is critical in the response to climate change.

Of Ethiopia's emissions contributions, food losses account for a significant proportion of emissions, particularly in smallholder value chains. The emissions associated with food loss across the agricultural value chains considered by the RE-GAIN

Programme for Ethiopia could amount to 959,809 tCO_2e for teff and 546,712 tCO_2e for wheat, based on smallholder production values. Without intervention, emissions related to post-harvest losses on smallholder farms in Ethiopia are expected to increase by between ~6% and ~16%. **For Ethiopia, this could amount to 581,337 tCO_2e for wheat and 108,667 tCO_2e for teff 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 require adaptation measures from field to market, occur during processing and on-farm storage of agricultural produce and are exacerbated by climate change. On-farm post-harvest losses in the teff value chain occur because of shattering, lodging, threshing, winnowing, and inefficient harvesting and threshing practices, as well as poor storage practices. The largest reported losses occur during storage, estimated at up to 4.2% of total production (Boxall, 1998; FAO Food loss and waste database, 2024). For wheat, on-farm post-harvest losses in the wheat value chain occur largely because of lodging, threshing, and inefficient household storage practices. Non-climate factors such as inadequate infrastructure, poor storage facilities, and limited access to markets also contribute to food losses in Ethiopia. Increased temperatures and humidity due to climate change worsen the already high post-harvest losses of teff and wheat, 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 Ethiopia's teff and wheat 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 Ethiopia. Successful implementation will require continued stakeholder collaboration, government support, and a focus on inclusivity to ensure that the benefits reach all segments of the agricultural sector.

1 Introduction

1.1 PROGRAMME BACKGROUND

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

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

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

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

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

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

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

1.2 BRIEF PROGRAMME DESCRIPTION

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

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

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

1.2.1 Target Countries Overview

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

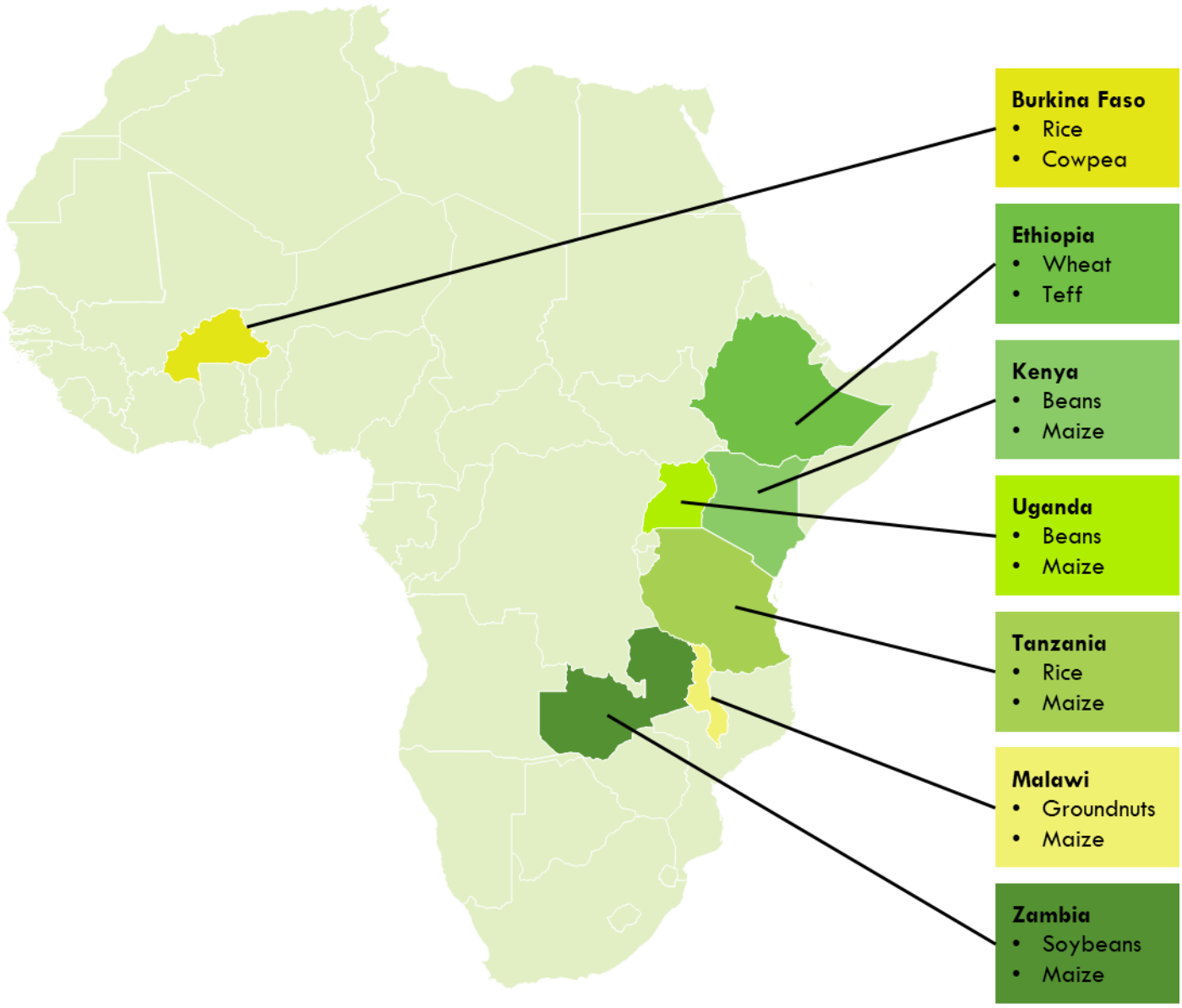


Figure 1-1 Focus Geographies for AGRA (2023-2027)

1.2.2 Crop selection

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

1.2.3 Harvesting and Post Harvesting Definition

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

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

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

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

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

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

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

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

1.3 REASONING FOR REQUESTED FUNDING

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

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

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

1.4 PROGRAMME GOAL STATEMENT

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

1.5 PURPOSE AND STRUCTURE OF THE REPORT

The purpose of this report is to provide an assessment of the climate hazards and vulnerabilities affecting each country and the distinct challenges they pose for the selected crops, and to propose a set of solutions designed to address these concerns. The analysis considers the country contexts, alongside the appropriateness of the solutions from an environmental, social, and financial perspective.

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

2 Country context

2.1 SITUATION ASSESSMENT

Agriculture is a cornerstone of the Ethiopian economy. In 2022, it contributed 37.6% to the nation's GDP (World Bank, 2023) **and provided employment for approximately 75% of the workforce.** Ethiopia's agricultural sector is characterized by diverse farming systems, which are integral to understanding the country's agricultural productivity and food security dynamics. With 80% of Ethiopia's population residing in rural areas, agriculture serves as the primary livelihood for the majority. The sector is predominantly characterized by smallholder farmers who practice rain-fed mixed farming, relying on traditional methods and technologies through the adoption of low-input and low-output production systems. These farmers cultivate a variety of crops, including cereals, pulses, oilseeds, fruits, and vegetables. Notably, staples such as teff, wheat, barley, and pulses have been integral to the Ethiopian diet for generations (United States International Trade Administration, 2024).

Smallholder farmers manage 95% of the land under agricultural use, producing over 90% of the total agricultural output. These farmers are responsible for 94% of food crop production and 98% of coffee, Ethiopia's leading export commodity. In contrast, private and state commercial farms contribute just 6% of food crops and 2% of coffee production, utilizing only 5% of the total cultivated land (IGAD, 2018). These farmers and respective rural communities have relatively low adaptive capacity to climate change and limited access to appropriate farming practices (FAO, 2015).

Crop production is the most significant sector followed by livestock in Ethiopia's agriculture-based economy. It accounts for nearly 80% of the cultivated land and employs 60% of the rural workforce, most of whom manage less than one hectare of land (FAO, 2015). Ethiopia stands as the largest wheat producer in Sub-Saharan Africa, with an annual domestic production of approximately 7.5 million metric tonnes, which meets about 75% of the domestic wheat demand (United States International Trade Administration, 2024).The country's rugged topography, fragmented landholdings, irregular rainfall, limited mechanization, and inadequate supplies of fertilizers and improved seeds contribute to relatively low grain yields per annum (FAO, 2015). Innovations in farming systems, such as the adoption of drought-resistant crop varieties and improved soil management techniques, can play a crucial role in mitigating these challenges and enhancing productivity (Dixon et al., 2019).

With smallholder farmers managing the majority of the land use, **Ethiopia's agricultural sector's growth is contingent on smallholder farmers' ability to maintain crop productivity through subsistence farming**. However, these farmers, operating within distinct farming systems, are highly vulnerable to climate variability. Sustainable agricultural intensification tailored to local resources and practices is necessary to enhance resilience and productivity (Dixon et al., 2019). Most of these farmers practice rain-fed mixed farming, making them highly dependent on rainfall. Consequently, these farming practices and smallholders are particularly vulnerable to climate variability (TradeGov, 2024).

Ethiopia's varied agro-climatic zones significantly influence agricultural productivity. The climate ranges from cool highlands, home to most subsistence farmers, to hot lowlands, which primarily support livestock grazing (FAO, 2020). This diversity in climate leads to significant variations in temperature and precipitation patterns across the country. According to the World Bank's Climate Knowledge Portal, Ethiopia experiences three distinct rainfall seasons: Bega, Belg, and Kiremt. The timing and duration of these seasons are influenced by the movement of the Intertropical Convergence Zone (ITCZ), which is affected by Indian Ocean sea-surface temperatures. Consequently, the onset and duration of rainfall seasons vary from year to year,

leading to frequent droughts (Ethiopia, 2022; WBCCKP, 2021). The Bega season occurs from October to January and is typically characterized by dry conditions, except in the southern regions where it is a lighter rainy season with about 100 mm of rainfall per month. This season is critical for farming systems that rely on early maturing crops and effective water management practices to ensure food security during the dry periods (Dixon et al., 2019). The Bega season is crucial for certain agricultural activities, such as land preparation and planting of early maturing crops in regions that receive some rainfall during this period. However, it is predominantly a dry season, impacting water availability and requiring effective water management practices to support agriculture (Ethiopia, 2022; WBCCKP, 2021). The Belg season runs from February to May and involves land preparation, planting, and the initial growth stages of various crops. Farmers focus on planting short-cycle crops such as barley, wheat, and pulses that can mature quickly with limited rainfall. This season is crucial for food security as it provides an early harvest that can sustain communities before the main harvest season begins (FAO, 2015; WBCCKP, 2021). The Kiremt season, extending from mid-June to mid-September, is the primary growing period characterized by more extensive agricultural activities. This season involves the planting, growing, and harvesting of major staple crops, including corn, wheat, sorghum, barley, and teff. The longer duration and more abundant rainfall during Kiremt allow for the cultivation of a wider variety of crops, which form the backbone of Ethiopia's agricultural production (FAO, 2015; WBCCKP, 2021).

Considering the broad classifications of farming systems from Dixon et al. (Farming Systems and Food Security in Africa: Priorities for Science and Policy under Global Change, 2019), matched with Ethiopia's specific agricultural characteristics, agroclimatic zones and types of crops and livestock we can infer that the country primarily subscribes to highland perennial, highland mixed, cereal-root crop mixed, and agropastoral farming systems. This classification helps in understanding Ethiopia's agricultural practices, challenges, and opportunities for targeted interventions to improve food security and resilience against climate change.

Climate significantly interacts with all three seasons, impacting crop yields and agricultural productivity. Rainfall patterns during the Belg season are often erratic and less reliable, making this period highly susceptible to climate variability. Early or delayed onset of rains can disrupt planting schedules and affect the growth of short-cycle crops. Conversely, the Kiremt season benefits from more predictable and consistent rainfall, which is essential for the successful cultivation of long-cycle crops. However, prolonged droughts or excessive rains during this season can lead to crop failures, soil erosion, and reduced agricultural output (FAO, 2015; WBCCKP, 2021) and associated harvest and post-harvest losses

The average annual temperature ranges from 15°C in the highlands to 30°C in the lowlands, with significant regional variations (World Bank, 2023; FAO, 2020). This climatic diversity makes Ethiopia a favourable region for growing various crops, but it also poses challenges due to climate variability and extremes. Smallholder farmers are highly dependent on these climatic conditions. Variations in rainfall patterns and increasing temperatures due to climate change have led to more frequent droughts, flooding, and unpredictable growing seasons, significantly affecting crop yields and food security (FAO, 2020; Ethiopia, 2022).

Agriculture and land use change in Ethiopia are major contributors to greenhouse gas (GHG) emissions, accounting for approximately 80% of domestic emissions. These emission-producing activities are summarised below, though it should be noted that rice production in Ethiopia covers only very small area.

Table 2-1 - GHG emitting agricultural practices in Ethiopia (FAO, 2015; IPCC, 2019)

Agricultural Practice	GHG Emissions	GHG Activity Description
Enteric Fermentation	Methane (CH4)	Methane is produced during the digestive process of ruminant livestock (e.g., cattle, sheep, goats).

Agricultural Practice	GHG Emissions	GHG Activity Description
Manure Management	Methane (CH4), Nitrous Oxide (N2O)	Emissions from the handling, storage, and application of livestock manure.
Rice Cultivation	Methane (CH4)	Methane is produced from the anaerobic decomposition of organic matter in flooded paddy fields.
Agricultural Soils	Nitrous Oxide (N2O)	Emissions from the application of synthetic and organic fertilizers, crop residues, and nitrogen-fixing crops.
Burning of Agricultural Residues	Carbon Dioxide (CO_2), Methane (CH4), Nitrous Oxide (N2O)	Emissions from open burning of crop residues used to clear fields and manage crop residues.
Deforestation and Land Use Change	Carbon Dioxide (CO_2)	CO_2 emissions from the loss of biomass and soil carbon due to the conversion of forests to agricultural land.

Teff and wheat are chosen as the primary focus of this study due to their significant roles in Ethiopia's agricultural landscape and food security. Teff, cultivated within highland perennial farming systems, and wheat, prominent in mixed farming systems, are both critical to understanding how different farming systems can be optimized to reduce post-harvest losses and enhance resilience to climate change. Teff, indigenous to Ethiopia, is a staple crop deeply integrated into the Ethiopian diet and culture, forming the basis of injera, a traditional Ethiopian bread. It is cultivated by a large proportion of smallholder farmers, covers about 30% of the land allocated for cereals and is crucial for both subsistence and commercial agriculture (FAO, 2015). Wheat, on the other hand, is a critical cereal crop for Ethiopia, being the largest producer in Sub-Saharan Africa. Domestic wheat production meets approximately 75% of the national consumption, highlighting its importance in reducing import dependency and ensuring food security (United States International Trade Administration, 2024). Both crops are highly sensitive to climate variability, which affects yield stability and post-harvest losses. By analysing the farming systems that produce teff and wheat, targeted interventions can be developed to improve storage, reduce losses, and enhance food security. These interventions must consider the specific needs and constraints of each farming system, leveraging local knowledge and innovations to build resilience.

2.2 TRENDS OF LAND USE CHANGE

In 2021, Ethiopia's agricultural land comprised approximately 38.7 million hectares, while forest land covered around 17 million hectares out of its total area of 113.6 million hectares. Out of those 38.7 million hectares designated for agricultural land in Ethiopia in 2021, about 18.8 million hectares were used for cropland, and around 20 million hectares were used as permanent meadows and pastures. Between 2019 and 2022, the forest land in Ethiopia decreased from 17,141.5 ha to 16 922.5 ha, primarily due to the increase of agricultural land (including arable land) (FAOSTAT, 2022). This trend of expanding agricultural areas at the expense of forested regions has significant implications for climate change, contributing to higher greenhouse gas (GHG) emissions due to deforestation and land use changes (IPCC, 2019). With an increasing population, there is a high probability of further encroaching to forest and other fragile areas unless crop and livestock productivity is enhanced through employing sustainable farming solutions.

Agriculture and land use are major sources of GHG emissions in Ethiopia, accounting for approximately 80 % of the country's total emissions (ARD Inc., 2004). The agriculture sector's vulnerability to climate change is heightened by its heavy reliance on natural resources and the relatively low adaptive capacity of rural communities. These areas frequently experience extreme weather events and long-term climatic variability, including droughts, floods, rainfall variability, and pest invasions (World Bank, 2023; FAO, 2015). Addressing these challenges requires a comprehensive approach to reduce yield gaps, land and

water management, including the promotion of sustainable agricultural practices, reforestation efforts, and enhanced support for rural communities to build resilience against climate impacts.

2.3 NATIONAL AND SECTORAL POLICY LANDSCAPE

Ethiopia's national policy landscape is shaped by a series of strategic frameworks and long-term plans aimed at fostering economic growth, sustainability, and resilience to climate change. Key among these are Ethiopia 2030: The Pathway to Prosperity - Ten Years Perspective Development Plan (2021 – 2030), and Ethiopia's Climate Resilient Green Economy Strategy (2011-2025). These policies provide overarching guidelines for development, integrating economic reforms with the sustainable development goals (SDGs), and aiming to build a resilient and prosperous economy. These can be summarised as follows:

Table 2-2 - Key national policies

Policy	Description	Climate Change Linkage
Ethiopia 2030: The Pathway to Prosperity - Ten Years Perspective Development Plan (2021 – 2030) **(Fedral Democratic Republic of Ethiopia, 2021)**	Successor to the Growth and Transformation Plan II (GTP II). Developed based on Ethiopia's vision for 2030, national policies, and the commitment to the SDGs. Focuses on agriculture, private sector leadership, and inclusive development with an emphasis on "women and youth."	Enhances resilience through investment climate, public-private partnerships, and sustainable development goals (SDGs).
Ethiopia's Climate Resilient Green Economy Strategy (2011-2025) **(Federal Democratic Republic of Ethiopia, 2011)**	Aims to achieve middle-income status by 2025 while fostering a climate-resilient green economy. One of its four pillars focuses on agricultural and land use efficiency measures, and another on increasing GHG sequestration through forest protection and re-establishment.	Targets adoption of agricultural efficiency measures and increasing GHG sequestration through reforestation and forest protection.
National Adaptation Plan (NAP) (2017) **(Federal Democratic Republic of Ethiopia, 2017)**	Guides Ethiopia's adaptation efforts in key sectors such as agriculture and forestry. Focuses on sustainable land management and reducing pre-harvest food losses.	Promotes technologies to reduce food loss and increase incomes, thus contributing to national adaptation objectives.
Ethiopia's updated Nationally Determined Contribution (NDC) **(Federal Democratic Republic of Ethiopia, 2021)**	Recognizes Land Use Change and Forestry (LUCF) as having the largest mitigation potential with ambitious reforestation and forest restoration targets. Emphasizes sustainable agriculture and reducing pre-harvest food losses.	Emphasizes sustainable agriculture and reduced pre-harvest food losses to achieve significant emission reductions.
Productive Safety Net Programme Phase IV (PSNP4) (2015-2020) **(Ministry of Agriculture, 2014)**	Enhances resilience to shocks and improves food security for vulnerable households. Launched to address increasingly unpredictable weather patterns, supporting low-input crop and livestock-based livelihoods vulnerable to climate changes.	Addresses climate vulnerability through adaptive measures and sustainable development initiatives.

The agricultural sector in Ethiopia is guided by various strategic frameworks aimed at enhancing productivity, sustainability, and climate resilience. Key policies include the Agricultural Transformation Agenda, Agricultural Sector Policy and Investment Framework (PIF) 2010-2020, and several sector-specific strategies such as the Agricultural Extension Strategy (2017-2030) and the Nutrition Sensitive Agriculture Strategy (2017-2021). These frameworks and policies and summarised below:

Table 2-3 - Key sectoral policies and frameworks

Policy	Description	Climate Change Linkage
Agricultural Transformation Agenda	Focuses on improving agricultural productivity and reducing post-harvest losses through the development of infrastructure, training, capacity building, and support for adopting post-harvest management technologies.	Enhances food security and reduces vulnerability to climate change impacts.

Policy	Description	Climate Change Linkage
Ethiopia's Agricultural Sector Policy and Investment Framework (PIF) 2010-2020	A strategic framework for the prioritization and planning of investments to drive agricultural growth and development. Aligned with Ethiopia's vision of becoming a middle-income country by 2025. Estimates that financing will need to come from Government and its development partners.	Aligns with sustainable development and climate resilience goals.
Agricultural Extension Strategy (2017-2030)	Integrates best practices and innovations for effective delivery of extension services to smallholder farmers. Analyses systemic bottlenecks and proposes strategic interventions to achieve its vision, mission, and objectives.	Promotes sustainable agricultural practices and addresses systemic bottlenecks.
Nutrition Sensitive Agriculture Strategy (2017-2021)	Mainstreams nutrition in all Ministry of Agriculture and Natural Resources (MoANR) programs with a strong focus on the empowerment of women through increased access to resources, inputs, and labour-saving technologies.	Reduces workload and increases resilience among women farmers through labor and energy-saving technologies.
Agriculture and Natural Resources Sector Growth and Transformation Plan II (2015-2020)	Aims to achieve broad-based, rapid, and sustainable sectoral development, focusing on high-value crops, industrial inputs, and export commodities. Emphasizes a climate-resilient green economy.	Enhances agricultural quality and competitiveness while building a climate-resilient economy.
Ethiopia's Post-harvest Management Strategy in Grains (2018)	Defines objectives and measures to reduce post-harvest losses in grains. Focuses on quantitative and qualitative reduction of food losses, improving market efficiencies, and supporting value addition.	Focuses on reducing food losses, improving market efficiencies, and supporting sustainable value addition.
Working Strategy for Strengthening Ethiopia's Teff Value Chain (2015)	A strategy to improve the production and profitability of teff farmers. Targets systemic obstacles in each value chain step and designs interventions to enhance teff productivity, profitability, and sustainability.	Enhances teff productivity and sustainability through systemic interventions.
Ethiopia's National Agriculture Investment Plan (NAIP) (2022)	Prioritizes sectoral investments aligned with national, regional CAADP, and global SDG commitments. Aims to end hunger and halve poverty by 2030 through sustainable and inclusive agricultural growth.	Enhances agricultural growth, food security, and alignment with sustainable development agendas.

Below, please find a summary of the key Ethiopian policies, as per the summarized tables above.

The Ethiopia's 10-year development plan is in line with the country's Homegrown Economic Reform Agenda and a successor to the country's five-year Growth and Transformation Plan II (GTP II). The plan was developed based on the nation's vision for 2030, national policies and strategies, and the commitment to the Sustainable Development Goals (SDGs). The plan focuses on agriculture, among other crucial development sectors. The development plan will also focus on "women and youth" and aim to ensure the leadership of the private sector in the economy. It aims to stimulate the increased participation of the private sector in the economy by creating a conducive investment climate, providing incentives and building public-private partnerships.

The Ethiopia's Climate Resilient Green Economy Strategy (2011-2025) aims to achieve middle-income status by 2025 while fostering a climate-resilient green economy. This strategy focuses on four main pillars, two of which are directly related to the report's objectives to minimise post-harvest food losses through climate change mitigation and adaption: 1) adopting agricultural and land use efficiency measures, 2) and increasing GHG sequestration through the protection and re-establishment of forests. By implementing these measures, the strategy seeks to mitigate climate change impacts, enhance

agricultural productivity, and reduce post-harvest losses. The strategy's emphasis on sustainable practices aligns with the need for climate-smart solutions to support smallholders.

Ethiopia's latest mid-term development plan, the Second Growth and Transformation Plan (GTP II) for 2015/16-2019/20, builds upon the foundations, objectives, and strategic directions established by the first Growth and Transformation Plan (GTP I) from 2010/11-2014/15. The primary goals include enhancing productivity among smallholder farmers and pastoralists, improving marketing systems, engaging the private sector, and developing irrigation and infrastructure. A significant focus is also placed on reducing the number of chronically food-insecure households. Agriculture continues to be the cornerstone of Ethiopia's rapid and inclusive economic growth and development. It is anticipated to drive growth in modern productive sectors. Besides focusing on the productivity and quality of staple food crops, the plan also prioritizes high-value crops, industrial inputs, and export commodities. There is a major emphasis on building a climate-resilient green economy within the framework of sustainable development, with the vision of becoming a lower-middle-income country by 2025. Ethiopia is recognized as a pioneer in the formulation and implementation of a climate-resilient green economy strategy. Therefore, efforts will be intensified to improve crop and livestock productivity, ensure food security, reduce emissions, protect forests, and support reforestation and carbon stock enhancement initiatives.

The Agricultural Transformation Agenda focuses on improving agricultural productivity and reducing post-harvest losses through the development of infrastructure, training, and capacity building. It supports the adoption of appropriate post-harvest management technologies, which are essential for minimizing food losses and enhancing food security. This agenda aligns with the report's objective by promoting initiatives that increase the availability and affordability of climate-smart solutions for smallholders, thereby enhancing their resilience to climate change.

Ethiopia's Post-harvest Management Strategy in Grains (2018) outlines specific objectives and measures to significantly reduce post-harvest food losses within the agricultural value chain. The primary aim of the strategy is to minimize food losses by adopting and implementing effective post-harvest management systems across Ethiopia's grain value chains. To achieve this goal, the strategy focuses on four key objectives:

1. **Reducing Food Losses**: Both quantitatively and qualitatively, the strategy targets reducing food losses along the agricultural value chains of grains.
2. **Improving Market Efficiencies**: Enhancing the efficiencies of agricultural input and output markets for grains to better support post-harvest management practices.
3. **Access to Financing**: Increasing access to financing and investment to improve practices related to post-harvest loss management.
4. **Supporting Value Addition**: Promoting sustainable value addition enterprises throughout the agricultural value chain to ensure comprehensive post-harvest management.

However, this post-harvest strategy was not implemented as planned due to low implementation capacity of the institutions, exacerbated by lack of financial and human resources.

Ethiopia's updated Nationally Determined Contribution (NDC) acknowledges that Land Use Change and Forestry (LUCF) possess the greatest mitigation potential, primarily due to ambitious targets for reforestation and forest restoration. Simultaneously, LUCF is identified as the second most significant source of emissions. This proposed project highlights the link between food loss and the expansion of agricultural land needed to offset productivity gaps caused by high levels of food

loss. By reducing food loss, the project can prevent unnecessary land expansion, thereby contributing to the NDC's goal of achieving net emission removals in LUCF.

A key policy and programmatic intervention in the NDC focus on sustainable agriculture, emphasizing sustainable land management, increasing land, water and nutrient use efficiency and the reduction of pre-harvest food losses. This approach supports the overall objective of enhancing climate resilience and sustainability in the agricultural sector. The total potential emissions reduction from this sector, as supported by the project, is projected to be 240.1 million tonnes of CO_2 equivalent ($mtCO_2eq$).

The National Adaptation Plan (NAP) (2017) guides Ethiopia's adaptation efforts in key sectors such as agriculture and forestry. It promotes technologies to reduce food loss and increase incomes, contributing to national adaptation objectives. The NAP's focus on sustainable land and water management and reducing pre-harvest food losses aligns with the report's objectives of enhancing agricultural resilience and supporting smallholders in adapting to climate change.

The Agricultural Extension Strategy (2017-2030) is designed to integrate best practices and innovative approaches to enhance the delivery of extension services to smallholder farmers. It addresses the systemic bottlenecks that have previously hindered effective operation, proposing a series of complementary and strategic interventions to achieve its vision, mission, and objectives. This strategy serves as a comprehensive framework for all agricultural sectors, including crops, livestock, fisheries, natural resource management, and other crosscutting issues.

A significant component of this strategy is the Nutrition Sensitive Agriculture Strategic Plan developed by the Ministry of Agriculture and Natural Resources (MoANR). This plan aims to incorporate nutrition into all MoANR programs, with a strong emphasis on women's empowerment. It focuses on increasing access to resources and inputs for women, promoting labour and energy-saving technologies to reduce women's workload, and ensuring gender sensitivity in nutrition-sensitive agriculture at all levels.

The overarching goal of the Agriculture and Natural Resources Growth and Transformation Plan is to help Ethiopia achieve its national target of becoming a middle-income economy. This involves fostering broad-based, rapid, and sustainable sectoral development that benefits all citizens, with particular emphasis on women and youth. The plan prioritizes maintaining the progress of previous sectoral developments, improving the quality and competitiveness of the agricultural sector, and ensuring the continued growth and transformation of agriculture in Ethiopia.

Ethiopia's National Agriculture Investment Plan (NAIP), published in 2022, integrates national priorities, the regional Comprehensive African Agriculture Development Program (CAADP), and global Sustainable Development Goals (SDGs). The plan aims to prioritize and guide investments in the agricultural sector to achieve several key objectives:

1. **Prioritizing Sectoral Investments:** The NAIP prioritizes the sectoral investment plan across the broad scope of the Ministry of Agriculture, ensuring focused and effective allocation of resources.
2. **Contributing to SDGs:** It aims to contribute to the Sustainable Development Goals (SDGs) by ending hunger and halving poverty in Ethiopia by 2030 through sustainable and inclusive agricultural growth and transformation.
3. **Aligning with CAADP Agendas:** The plan aligns the sector priorities with CAADP development agendas to ensure coherence and synergy with regional agricultural development goals.
4. **Enhancing Agricultural Growth:** NAIP focuses on rapid and sustainable growth of the agriculture sector to create employment, drive economic growth, and ensure food and nutrition security. This involves identifying priority flagship programs under each Strategic Objective (SO).

5. **Estimating Financial Requirements:** It estimates the financial requirements for the implementation of the plan, identifies possible funding sources, and provides a framework for governance, coordination, and tracking results and review mechanisms.

The NAIP serves as a comprehensive framework to mobilize resources, coordinate efforts, and monitor progress towards achieving sustainable agricultural development in Ethiopia.

In 2015, the Government of Ethiopia introduced the Working Strategy for Strengthening Ethiopia's Teff Value Chain. This strategy aims to align all stakeholders within the teff industry on a unified, comprehensive plan to enhance the production and profitability of teff farmers, while also creating better opportunities for teff consumers. The overarching goal is to transform Ethiopia's agricultural sector by promoting teff, one of its primary crops.

The strategy focuses on improving teff productivity, profitability, and sustainability through a series of comprehensive, actionable interventions. To achieve these objectives, the strategy:

1. **Identifies and Prioritizes Systemic Obstacles**: It systematically identifies and prioritizes the key challenges at each step of the teff value chain.
2. **Designs and Prioritizes Interventions**: It develops and ranks interventions necessary for the successful implementation of the strategy.
3. **Addresses Obstacles with Key Activities**: It tackles the identified obstacles through a set of targeted, actionable interventions and activities.

This strategic approach aims to enhance the efficiency and effectiveness of the teff value chain, ultimately contributing to the broader goals of agricultural transformation and economic development in Ethiopia.

2.3.1 Productive Safety Net Programme Phase IV (PSNP4) (2015-2020)

From 2015 to 2020, the Ethiopian government developed a Productive Safety Net Programme Phase IV (PSNP4), in which the Ethiopian Government has implemented several innovative and effective mechanisms aimed at increasing the households' and communities' resilience. The programme was particularly focussed on reducing the impact of climate shocks and stresses, while committing to a green, low carbon development path.

PSNP Phase IV (2015-2020) was launched with the objective of enhancing resilience to climate shocks, improving livelihoods, and bolstering food security and nutrition for rural households that are vulnerable to food insecurity. This phase of the programme forms part of the Ethiopian Government's broader response to the increasingly unpredictable weather patterns in the Horn of Africa, which have made traditional low-input crop- and livestock-based livelihoods more susceptible to long-term changes in rainfall and temperature, as well as an increased frequency of extreme weather events such as droughts and floods.

PSNP4 contributes to both adaptation and mitigation goals by improving the resilience of rural communities, enhancing their capacity to withstand and recover from climatic shocks, and promoting sustainable agricultural practices that support a low carbon development trajectory.

2.4 LEGAL AND REGULATORY LANDSCAPE

Besides the range of national policies, strategies, plans, and programs mentioned in the previous subchapter, some of Ethiopia's legal acts are related to agriculture, specifically harvest and post-harvest food losses, as well as climate change mitigation and adaptation.

Specifically, among other proclamations, Paris Agreement Ratification Proclamation No.993/2017 was officially ratified on 22 April 2016 (Republic of Ethiopia, 2017). The Ministry of Environment, Forest and Climate Change is hereby authorized to implement this Agreement in collaboration with the appropriate Federal and Regional Government Organ, City Administrations, and International, National, and Domestic Institutions.

2.5 GCF COUNTRY PROGRAMME DETAILS

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

Green Climate Fund (GCF) in Ethiopia has so far implemented (or implementing) 8 projects (Table 2-4), with a total GCF financing of 29 million USD. It has approved so far 5 country-level readiness activities, with a total budget of 4.5 million USD in readiness support approved and 2.6 million USD in readiness support disbursed.

Table 2-4 - GCF portfolio in Ethiopia (Green Climate Fund, 2024)

Project code	Project title	Focus	Geographical scope
FP204	Sustainable Renewables Risk Mitigation Initiative (SRMI) Facility (Phase 2 Resilience focus) [SRMI-Resilience)	Cross-cutting	Africa, Asia-Pacific (Ethiopia, Indonesia, Mongolia, Somalia, Tunisia, Guinea-Bissau, Kyrgyzstan, Seychelles, Tajikistan)
FP183	Inclusive Green Financing Initiative (IGREENFIN I): Greening Agricultural Banks & the Financial Sector to Foster Climate Resilient, Low Emission Smallholder Agriculture in the Great Green Wall (GGW) countries - Phase I	Cross-cutting	Africa (13 countries)
FP168	Leveraging Energy Access Finance (LEAF) Framework	Mitigation	Africa (Ethiopia, Guinea, Nigeria, Ghana, Kenya, Tunisia)
FP136	Resilient Landscapes and Livelihoods Project	Cross-cutting	Ethiopia
FP128	Arbaro Fund – Sustainable Forestry Fund	Mitigation	Latin America and the Caribbean, Africa (9 countries)
FP099	Climate Investor One	Mitigation	Africa, Latin America and the Caribbean, Asia-Pacific (19 countries)
FP058	Responding to the increasing risk of drought: building gender-responsive resilience of the most vulnerable communities	Adaptation	Ethiopia
FP027	Universal Green Energy Access Programme (UGEAP)	Mitigation	Africa (Benin, Kenya, Uganda, Nigeria, Ethiopia, Namibia, Tanzania)

Key projects in Ethiopia's agricultural sector include FP136 “Resilient Landscapes and Livelihoods Project,” FP183 “Inclusive Green Financing Initiative (IGREENFIN I): Greening Agricultural Banks & the Financial Sector to Foster Climate Resilient, Low Emission Smallholder Agriculture in the Great Green Wall (GGW) countries - Phase I,” and FP058 “Responding to the increasing risk of drought: building gender-responsive resilience of the most vulnerable communities.”

FP136: Resilient landscapes and livelihoods project

This 297.2 million USD project, implemented from November 2021 to November 2026, aims to enhance climate resilience, land productivity, and carbon storage. It also seeks to increase access to diversified livelihood activities in vulnerable rural watersheds of Ethiopia. The current study can examine how reducing food losses can contribute to resilient landscape use and identify potential synergies.

FP183: Inclusive green financing initiative (IGREENFIN I)

This initiative, valued at 190.4 million USD and implemented from January 2024 to January 2030, is designed to green agricultural banks and the financial sector to support climate-resilient, low-emission smallholder agriculture in the Great Green Wall countries. Led by IFAD, it enhances access to credit and technical assistance for local farmers, farmer organizations, cooperatives, and micro and small enterprises. The funding mechanisms of this project should be evaluated for their suitability in financing food loss reduction solutions.

P058: Responding to the increasing risk of drought

This 50 million USD project, running from February 2019 to August 2023, aimed to build gender-responsive resilience in the most vulnerable communities by providing essential water supplies for year-round drinking water and small-scale irrigation to mitigate drought risks and other climate impacts. The project's engagement with rural communities and its focus on gender responsiveness can be valuable considerations for the current project design.

2.5.2 Other relevant projects (on food losses)

Ethiopia has recently launched several significant agricultural projects aimed at improving productivity, income, and food security in the face of climate change and global disruptions. Key among these are the Climate Resilient Wheat Value Chain Development Project (CREW) and two USAID-supported initiatives: Feed the Future Ethiopia Transforming Agriculture and Feed the Future Ethiopia Seed Systems.

Climate resilient wheat value chain development project (CREW)

One of the most recent initiatives is the Climate Resilient Wheat Value Chain Development Project (CREW) (African Development Bank, 2023)**.** Funded by the African Development Bank and other partners, CREW aims to enhance wheat production and increase farmers' incomes. The project is supported by 54 million USD from the African Development Fund, 20 million USD from the Government of the Netherlands, 10 million USD from OCP Africa, and 300 000 USD from the Global Center on Adaptation. The Ethiopian government will contribute 10 million USD in counterpart funding. The project comprises three components: Climate Smart Wheat Productivity and Production; Market Infrastructure, Linkages, and Agri-Finance; and Project Coordination and Management.

Under the Technologies for African Agricultural Transformation (TAAT) initiative, the African Development Bank Group has helped Ethiopia and other African countries boost agricultural productivity. CREW aims to scale up and sustain the successes achieved under TAAT. The project, supporting Ethiopia's wheat self-sufficiency initiatives, will be implemented over five years and benefit 500 000 small-scale farmer households. By ensuring access to agricultural inputs, CREW will help increase local wheat production, mitigating food security risks exacerbated by the Russia-Ukraine crisis, COVID-19, climate change, and rising living costs. Additionally, CREW seeks to sustain Ethiopia's progress towards wheat self-sufficiency and export orientation, serving as a model for other African nations.

USAID Feed the future Ethiopia projects

On March 5, 2024, the USAID Economic Growth and Resilience Office, in collaboration with the Ministry of Agriculture of Ethiopia, launched two new projects: the 77 million USD Feed the Future Ethiopia Transforming Agriculture and the 9.5 million USD Feed the Future Ethiopia Seed Systems projects. These initiatives aim to increase incomes and reduce malnutrition rates in Ethiopia.

- Feed the Future Ethiopia Transforming Agriculture: This five-year project will support agricultural and food system actors in Ethiopia to sustainably improve the diets of 7 million people, particularly women and children. It targets 132 woredas across the country, working with agribusinesses, universities, and other partners to develop resilient, inclusive, and sustainable agricultural and food systems.
- Feed the Future Ethiopia Seed Systems: Also, a five-year project, this initiative aims to increase the supply of quality-assured seeds in local markets, ensuring that smallholders have access to high-quality seeds of their preferred crop varieties. The project will be implemented across 20 woredas in eight regions, collaborating with various agricultural partners to enhance seed quality and availability.

These projects reflect Ethiopia's ongoing commitment to improving agricultural productivity and resilience in the face of climate challenges and global disruptions.

3 Climate analysis - Adaptation

3.1 COUNTRY CLIMATE CHANGE BASELINE

Ethiopia has a complex and diverse climate pattern with highly variable distribution of rainfall and temperature. According to the Köppen climate classification, Ethiopia has several distinctly identifiable climate regions in its landscape. These include the Hot/Arid or warm/desert Climate (Bwh), the Hot/warm Semi-Arid Climate (Bsh), Tropical Savanna Climate (Aw) with distinct dry winter, Tropical Monsoon Rainy Climate (Am) with short dry winter, Warm Temperate Rainy or Subtropical Oceanic highland Climate (Cwb) with dry winter, Warm Temperate Rainy or Oceanic Climate (Cfb) without distinct dry season, Humid subtropical climate (Cwa) and Temperate Mediterranean Climate (Csb) (Ethiopia, 2022).

As described in the Situation assessment, **Ethiopia experiences three distinct rainfall seasons: Bega, Belg, and Kiremt** The timing and duration of these seasons are influenced by the movement of the Intertropical Convergence Zone (ITCZ), which in turn is affected by Indian Ocean sea-surface temperatures. Consequently, the onset and duration of rainfall seasons vary from year to year, leading to frequent droughts (Ethiopia, 2022). The lowlands in the southeast and northeast are tropical, with average temperatures of 25°-30°C, while the central highlands are cooler, with average temperatures of 15°-20°C.

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, 2021):

- Temperature increases of approximately 1°C, with the increases being most noticeable from July through September;
- An increase in the number of hot days and nights by 20% and 37.5%, respectively;
- Highly variable year-to-year rainfall totals with no statistically significant trends;
- 20% decrease in rainfall experienced over the south-central region and increases experienced in the western highlands;
- An increase in sea surface temperature further increases variability in the timing and duration of rainfall seasons, leading to increased droughts, which are noticeable over the central and northern areas.

In recent decades, the trend of increased average temperatures has been even more pronounced, as depicted in Figure 3-1, Figure 3-2, and Figure 3-3.

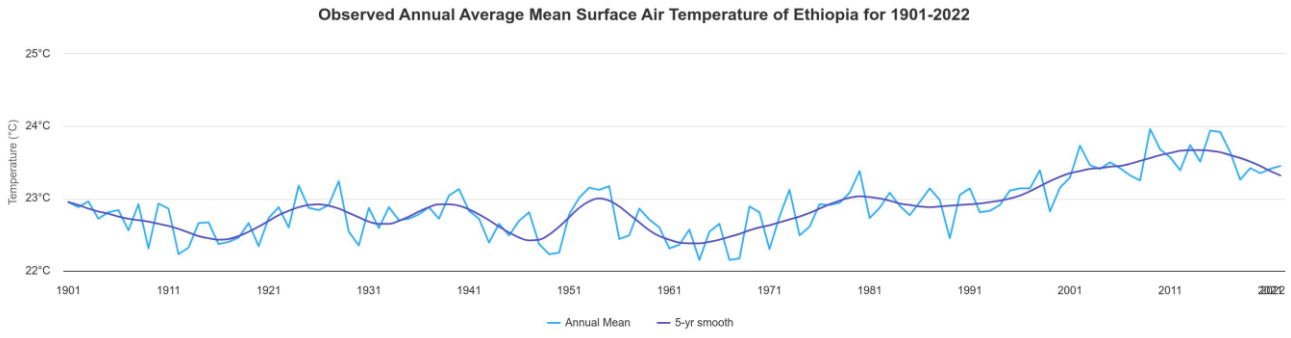


Figure 3-1 - Observed annual average mean surface air temperature of Ethiopia, 1901 - 2022 (WBCCKP, 2021)

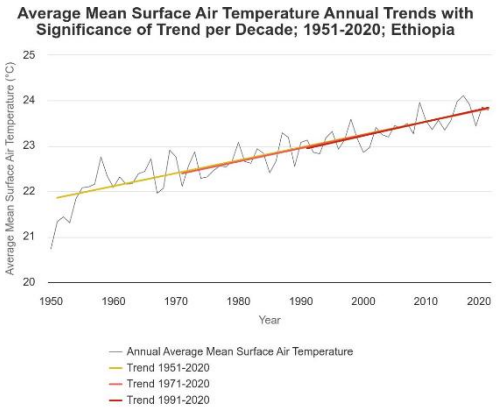


Figure 3-2 - Average mean surface air temperature annual trends with significance of trend per decade, 1951 - 2020, Ethiopia (WBCCKP, 2021)

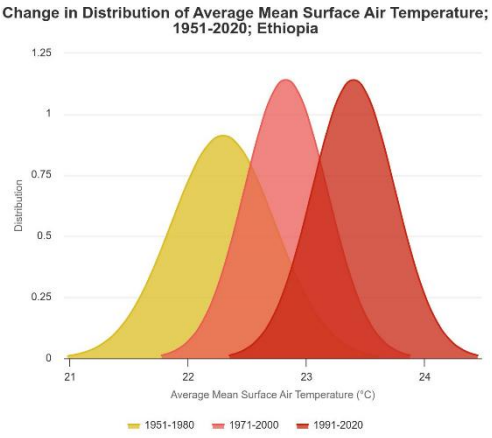


Figure 3-3 - Change in distribution of average mean surface air temperature, 1951-2020, Ethiopia (WBCCKP, 2021)

Observed mean annual rainfall trends for Ethiopia highlight an extremely high degree of inter-annual variability (The World Bank, 2021). In the western highlands, there's been a rise in average yearly rainfall, while the northeastern highlands have seen a decline during the same timeframe. This indicates that rainfall patterns are becoming increasingly unpredictable, with a projected increase in extreme weather events. Consequently, Ethiopia may undergo significant alterations in the distribution of seasonal rainfall. The timing and location of the brief rainy season could change, posing a serious threat to food production and rural livelihoods, especially in the arid and semi-arid lowlands, including the Rift Valley (Ethiopia, 2022). The projections for the future show that temperature will rise within a range of 0.5°C to 2°C by the 2050s relative to the current state.

Another recent study of historic rainfall in Ethiopia (1980 to 2010) confirms that observed rainfall is characterized by high temporal variability (Gummadi, et al., 2018). Over this period, **rainfall variability increased disproportionately as the amount of rainfall declined** from 700 mm to 100 mm or less. In this study, no significant trend was observed in the annual rainfall amounts over the country, but increasing and decreasing trends were observed in the seasonal rainfall amounts in certain areas. **A declining trend was also observed in the number of rainy days** (Gummadi, et al., 2018).

Ethiopia faces various hazards, including droughts and floods among others. Recurring droughts and floods have intensified since the 1970s, with the 2011 Horn of Africa drought leaving over 4.5 million people in need of food assistance due to livestock deaths and water shortages. Climate change and human-induced factors are expanding areas affected by drought and desertification, while flash floods and seasonal river floods are becoming more frequent. Projections suggest a 20% increase in extreme high rainfall events by the end of the century (Ethiopia, 2022).

Table 3-1 summarizes past hazards and the implications thereof. Drought stands out as the most devastating climate-related natural disaster in Ethiopia. Projections indicate that by 2045, climate change could lead to a decrease in Ethiopia's GDP by up to 10%, primarily due to the adverse effects of drought on agricultural output (CGIAR, 2018).

Table 3-1 - Natural disasters in Ethiopia, 1900-2020 (WBCCKP, 2021)

Natural Hazard 1900–2020	Subtype	Events Count	Total Deaths	Total Affected	Total Damage ('000 USD)
Drought	Drought	16	402,367	77,141,879	1,492,600
Earthquake	Ground Movement	2	24	585	320
Epidemic	Bacterial Disease	16	10,999	134,551	0
	Viral Disease	6	156	4,819	0
	Parasitic Disease	1	157	25,000	0
Flood	Flash Flood	9	863	1,129,358	9,400
	Riverine Flood	32	1,105	1,809,978	8,900
Insect Infestation	Locust	4	0	0	0
Landslide	Landslide	5	93	215	36
Mass Movement (dry)	Landslide	1	13	0	0
Volcanic Activity	Ash Fall	3	69	11,000	0
Wildfire	Forest Fire	1	0	5	0

The most recent Germanwatch climate risk index for cumulative disaster-related losses between 2000-2019 ranks Ethiopia 60th out of 180 countries (Eckstein, Künzel, & Schäfer, 2022). According to the EU's INFORM climate risk index, Ethiopia's baseline risk level comprises an above-average vulnerability to climate-related hazards (6.4 out of 10), and a high lack of coping capacity (6.8 out of 10) (European Commission, n.d.).

3.2 AGRICULTURE SECTOR CLIMATE CHANGE BASELINE

Ethiopia's agriculture sector is particularly susceptible to the effects of climate change since it relies heavily on rainfall and is primarily made up of small-scale subsistence farmers (FAO, 2019). Farmers use low-intensive technology and have limited access to financial and technical services. The agriculture sector plays a major role in Ethiopia's economy, contributing 34% of GDP (World Bank, 2021).

As discussed in the Situation assessment Crop agriculture in Ethiopia is diverse, with significant variations in the types of crops cultivated across various regions and ecological zones. The agricultural landscape is anchored by five main cereals: teff, wheat, maize, sorghum, and barley (AGRICA, 2020). Teff cultivation accounts for 28% of total cereal crops harvested in Ethiopia in 2021/22 and is thus a principal driver of agricultural land use (USDA, 2022). This is followed closely by corn (24%) and wheat (18%) as seen in Table 3-2.

Table 3-2 - Area and production estimates of common cereals in Ethiopia FY 2021/22 (Adapted from: United States Department of Agriculture)

Crop	Area (1000ha)	Production (1000MT)	Productivity (MT/Ha)
Teff	2 983	5 735	1.9
Maize (Corn)	2 530	9 400	3.7
Wheat	1 950	5 520	2.83
Sorghum	1 650	4 550	2.7
Barley	960	2 350	2.4
Millet	460	1 173	2.55

Climate change will have a negative impact on both teff and wheat, which are the most important staple crops in terms of caloric intake, number of farmers growing it, and production volume in Ethiopia (Abate, et al., 2015). Both crops are sensitive to changes in temperatures and rainfall and, according to modelled predictions, yields are likely to decrease under a variety of climate change scenarios (AGRICA, 2020).

The IPCC's synthesis of global literature on observed climate change impacts on major crops indicates that wheat yields, and – more broadly - all cereal crops, which includes Teff, in sub-Saharan Africa have displayed negative trends under a steadily warming climate, as captured in Figure 3-4.

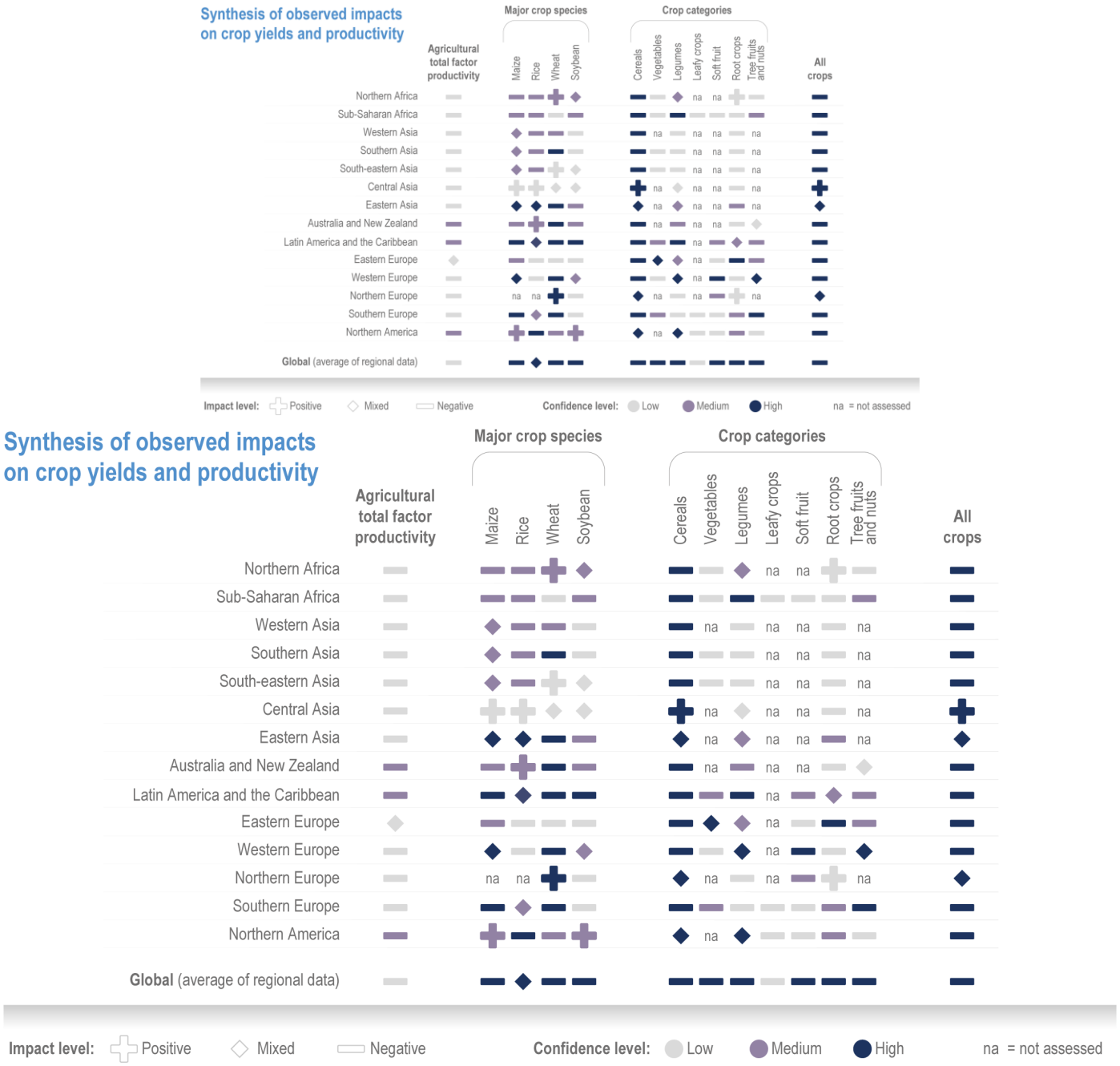


Figure 3-4 - Synthesis of literature on observed impacts of climate change on productivity by crop type and region (IPCC, 2021)

Although drought is particularly detrimental to food security, other factors such as flooding, frost, hailstorms, and changes in seasonality also have significant repercussions on agriculture. Major cereal crops such as teff, maize wheat, barley, and sorghum are particularly at risk. This threat is exacerbated by insufficient investments and the slow adoption of new agricultural technologies, uncertainty regarding the timing of field operations, and the rising frequency of extreme weather events (Kassaye, Shao, Wang, Shifaw, & Wu, 2021).

Between 1988 and 2018, maize and sorghum exhibited higher annual growth rates in national cereal production (3.95% and 3.74%, respectively) compared to wheat (3.31%) and teff (3.04%). However, from 2013/2014 to 2017/2018, there was a consistent decline in cereal production across all major crops. Two key factors contributed to this decline: extensive drought in 2015 due to the El Niño-Southern Oscillation (ENSO), and reduced government involvement and incentives in agricultural extension programs due to ongoing political opposition. From 2002/2003 to 2016/2017, the annual average yield growth rate was generally rapid for all crops except in 2006/2007 and 2015/2016, attributed to drought (Kassaye, Shao, Wang, Shifaw, & Wu, 2021). see Figure 3-5 and Figure 3-6 taken from Kassaye et al. (Impact of climate change on the staple food crop yields in Ethiopia: implications for food security, 2021) depicts the annual growth rate percentages for three parameters related to teff and wheat in Ethiopia: area cultivated, yield, and production, over the period from 1988 to 2018. All three parameters show high variability year over year. In some years, the area cultivated and production growth rates move together (e.g., around 2000 and 2006), suggesting that changes in area cultivated significantly impact total production. From 2002 to 2018, the yield growth rate has demonstrated an upward trend, with fluctuations caused by year-to-year variability attributed to climatic conditions. The variability of these crops underscores the challenges and opportunities in teff & wheat agriculture, which may be influenced by external factors such as weather patterns, agricultural practices, and economic conditions.

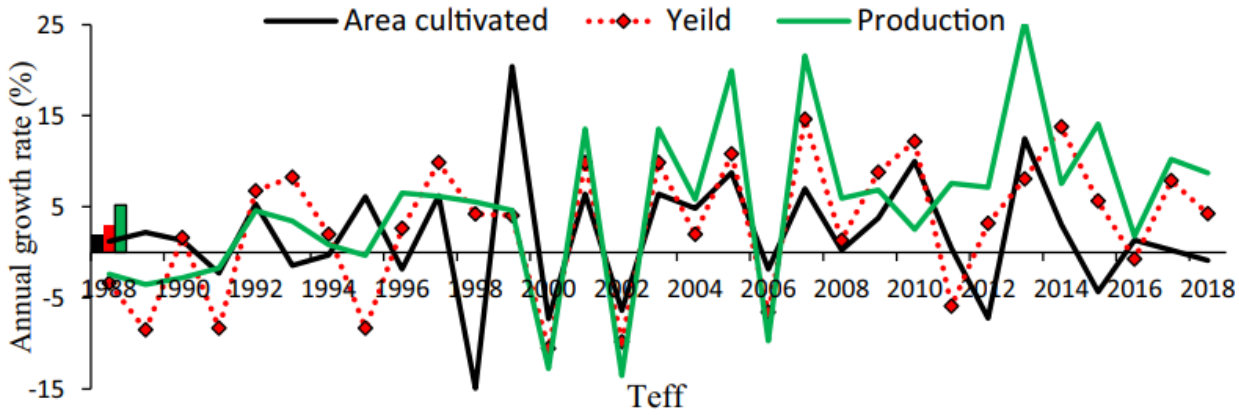


Figure 3-5 - Historical annual growth rate of teff yield, total production, and area cultivated from 1988 to 2018 in Ethiopia (Kassaye, Shao, Wang, Shifaw, & Wu, 2021)

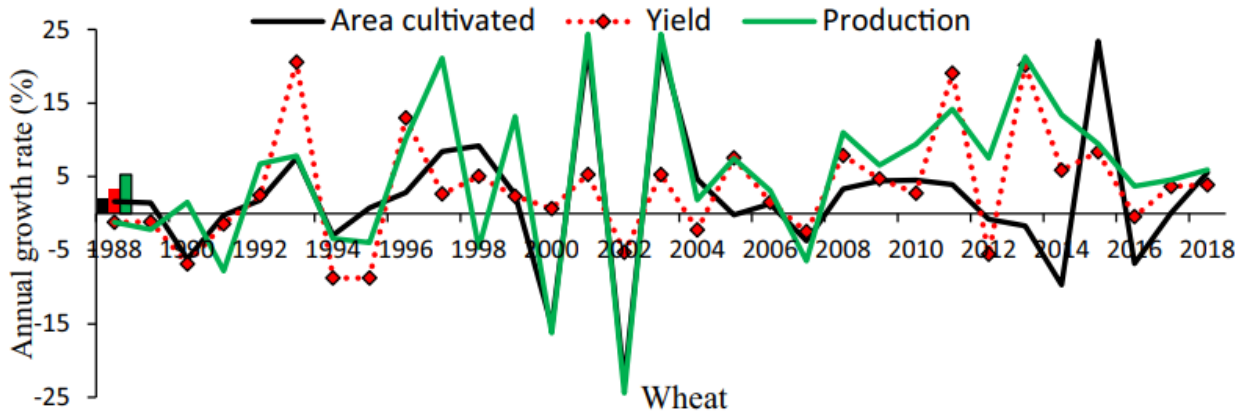


Figure 3-6 - Historical annual growth rate of wheat yield, total production, and area cultivated from 1988 to 2018 in Ethiopia (Kassaye, Shao, Wang, Shifaw, & Wu, 2021)

While cereal production in Ethiopia has been increasing historically, much of this growth has been driven by expanding cultivated areas and increased use of agricultural inputs. Despite this, Ethiopia's cereal productivity remains below the global average yield gain per hectare according to (Worldometer, n.d.) data. This low productivity is attributed to both environmental factors such as floods, pests, recurrent droughts, and diseases, as well as social factors like poor agronomic practices, soil fertility loss, limited access to technology and credit, and poor seed quality, all of which will be exacerbated by climate change (Kassaye, Shao, Wang, Shifaw, & Wu, 2021).

3.3 COUNTRY CLIMATE CHANGE FUTURE

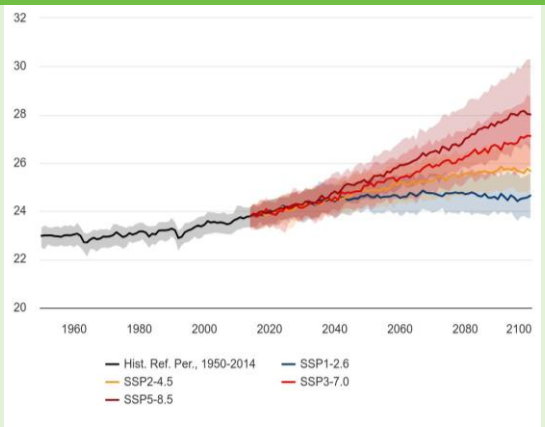
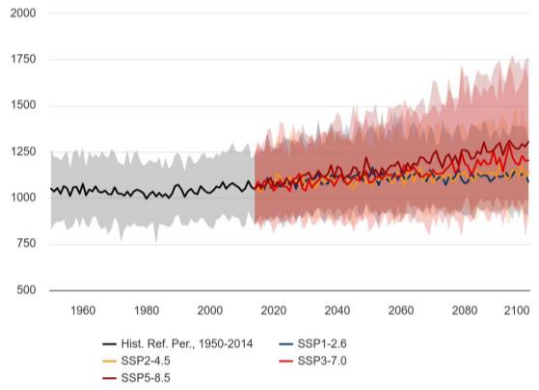
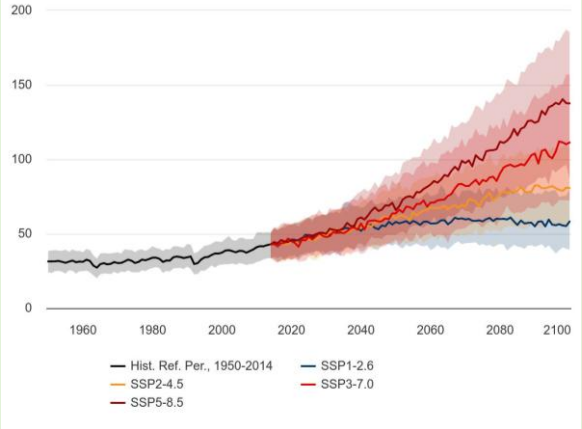
For the analysis of future climate risk to the two crops of interest, Teff and Wheat, our assessment looks at the 2040-time horizon (a timescale relevant to RE-GAIN's programmatic interventions). To identify future climate conditions that would (i) signal the major climate-driven threats that could impact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

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

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

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

Table 3-3 - Principal Climatic Variables (World Bank, 2024)

Variable Name	In-Country Context Description	Additional information
Average Mean Surface Temperature	Across all future climate scenarios, **the average mean surface temperature in Ethiopia 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 estimated rise in temperature from the historic baseline is **very high**.	 *Figure 3-7 - Projected average mean surface temperature under multiple future scenarios (WBCCKP, 2021)*
Mean Precipitation	Across all future climate scenarios, Ethiopia's **average mean precipitation is expected to rise**, relative to the historic baseline. In our analysis of the expected difference in the mean annual precipitation in 2040 between the two future scenarios, we observed that the estimated **rainfall increase from the historic baseline** is **very high.**	 *Figure 3-8- Projected mean precipitation under multiple future scenarios (WBCCKP, 2021)*
Number of Hot Days over 35°C	Across all future climate scenarios**, the average number of hot days with temperatures 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). In the past there were already, on average 30 such days in the year. Future projections of potentially 60 (SSP 2-4.5) or even 70 (SSP 5-8.5) such days in 2040 represent 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 3-9 - Projected change in the number of hot days with temperatures over 35°C, under multiple future scenarios (WBCCKP, 2021)*

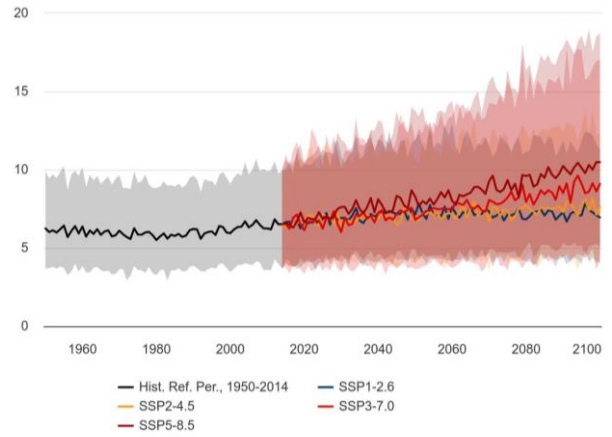
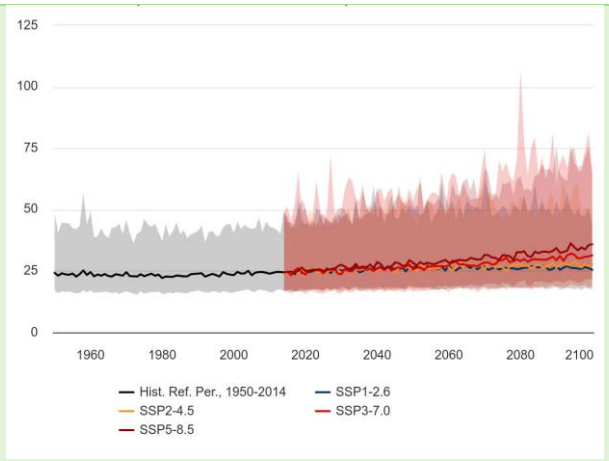
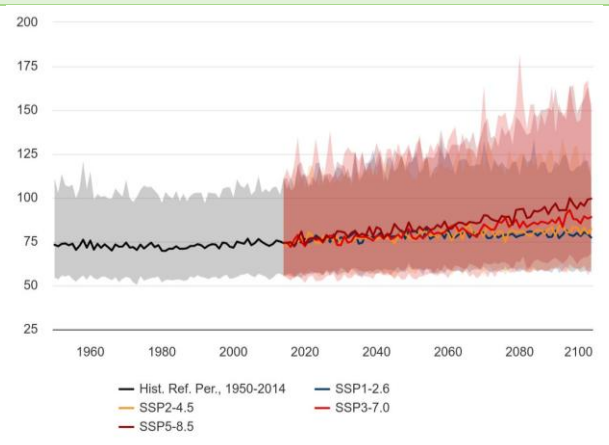
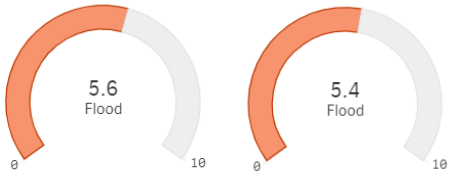
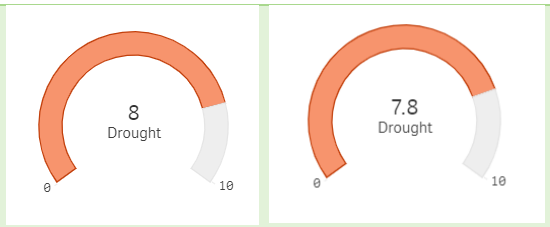
Variable Name	In-Country Context Description	Additional information
Number of Days with Precipitation >20 mm	Across all future climate scenarios, the average number of days with rainfall greater than 20mm displays a rising trend (except SSP1-2.6). The trend does demonstrates a **particularly marked increase from the historic baseline** (reference period 1950-2014). Given that in the past there were on average 6.07 such days in the year, projections of potentially ~7.05 (SSP 2-4.5) or ~7.99 (SSP 5-8.5) such days in 2040 shows a notable percentage change. Thus, in our assessment, we found that the estimated change in the number of days with precipitation >20 mm is **very high.**	 *Figure 3-10 - Projected change in number of days with rainfall >20 mm, under multiple future scenarios (WBCCKP, 2021)*
Average Largest 1-day Precipitation	Across all future climate scenarios, the average largest single-day (1-day) precipitation (a measure of heavy rainfall events) shows a constant increase compared to the historic baseline. There is an **apparent increasing signal near the end of the century**, but the increase for the 2040 period is more modest. Nonetheless, when we compared the anticipated change in single-day rainfall between the two future scenarios to the baseline, we observed that the estimated change was **very high** (with an increasing signal).	 *Figure 3-11 - Projected change in average largest single-day precipitation, under multiple future scenarios (WBCCKP, 2021)*
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 steady increase, relative to the historic baseline (reference period 1950-2014). The rainfall levels may increase substantially towards the end of the century, with a more modest increase for the 2040 period. 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 very high** (with an increasing signal).	 *Figure 3-12 - Projected change in average largest five-day precipitation, under multiple future scenarios (WBCCKP, 2021)*

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

Variable Name	In-Country Context Description	Additional Information
Extreme Heat/ Heatwaves	Ethiopia'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." (GFDDR, n.d.) [Note: the INFORM climate risk index does not provide data for extreme heat/heatwaves.]	N/A
Floods	Ethiopia'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" (GFDDR, n.d.). According to the INFORM Climate Change Risk Index, Ethiopia's baseline risk of flooding (on a 0-10 scale) is 5 as of 2022. Under the SSP2-4.5 scenario for mid-century (2050), this rises to 5.5, and under the SSP5-8.5 scenario this decreases slightly to 5.4 for the same period (European Commission, n.d.).	 *Figure 3-13- Ethiopia's future flood risk in 2050 under SSP2-4.5 and SSP5-8.5, on a scale of (INFORM Climate Risk Index, 2024).*
Water Scarcity (linked to Drought)	According to the INFORM Climate Change Risk Index, Ethiopia's baseline risk of drought (on a 0-10 scale) is already high at 7.2 as of 2022. Under the SSP2-4.5 scenario for mid-century (2050), this rises to 8, and under the SSP5-8.5 scenario However, this decreases slightly to 7.8 for the same period (European Commission, n.d.). Ethiopia's future water scarcity risk in the face of climate change is regarded as **moderate (medium)**. This implies that "there is up to 20% chance droughts will occur in the coming 10 years." (GFDDR, n.d.).	 *Figure 3-14 - Ethiopia's future drought risk in 2050 under SSP2-4.5 and SSP5-8.5, on a scale of 10 (INFORM Climate Risk Index, 2024)*
Wildfire	Ethiopia'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." (GFDDR, n.d.). [Note: the INFORM climate risk index does not provide data for wildfires.]	N/A

Variable Name	In-Country Context Description	Additional Information
Landslide	Ethiopia's future landslide risk due to climate change (and other factors) is regarded as **high**. This indicates that the "area has rainfall patterns, terrain slope, geology, soil, land cover, and (potentially) earthquakes that make localized landslides a frequent hazard phenomenon." (GFDDR, n.d.). [Note: the INFORM climate risk index does not provide data for landslides.]	N/A
Cyclones	Ethiopia's future tropical cyclone (or hurricane) risk due to climate change (and other factors) is regarded as low. This denotes that "there is a 1% chance of potentially damaging wind speeds in the area in the next 10 years." (GFDDR, n.d.). According to the INFORM Climate Change Risk Index, Ethiopia's baseline risk of cyclones (on a 0-10 scale) is 0 as of 2022. Under both the SSP2-4.5 scenario and the SSP5-8.5 scenario this remains at 0 for the same period (European Commission, n.d.)	 *Figure 3-15 - Ethiopia'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)	N/A
Sea Level Rise	Not applicable (inland country without an oceanic coastline).	N/A

3.4 THE FUTURE OF CROP AGRICULTURE UNDER CLIMATE CHANGE

3.4.1 Teff

Two of the main projected climate impacts on teff production in Ethiopia are rising temperature and variability in rainfall patterns. Modelling outputs from a World Bank Group study indicate that the effects of climate change on crop yields will differ depending on the crop type and the region, and not all impacts will be detrimental (The World Bank Group, 2024). Table 3-5 below illustrates the effects on crop yields for six major Ethiopian crops under various climate scenarios. Teff, maize, wheat, and barley yields show negative impacts in dry/hot scenarios. Teff is the sole crop to experience a decrease in a wet/warm scenario, while all other crops demonstrate increased yields. Additionally, the impacts vary across different regions. Figure 3-16 depicts yield changes for teff from 2001–2020 to 2041–2060 under average hot and dry climate models. Yield reductions are not consistent across the country; certain regions in the highlands benefit from climate change impacts, while the lowlands experience negative effects.

Table 3-5 - Average change in crop yields under climate change from 2001-2020 to 2041-2060 (The World Bank Group, 2024)

Crop	Climate effect (Dry/Hot mean)	Climate effect (Wet/Warm mean)
Teff	-5.5%	-2.8%
Maize	-1.5%	+1.3%
Sorghum	+2.9%	+3.1%
Wheat	-1%	+3.8%
Barley	-6.6%	+2.4%
Chickpea	+5.8%	+4%

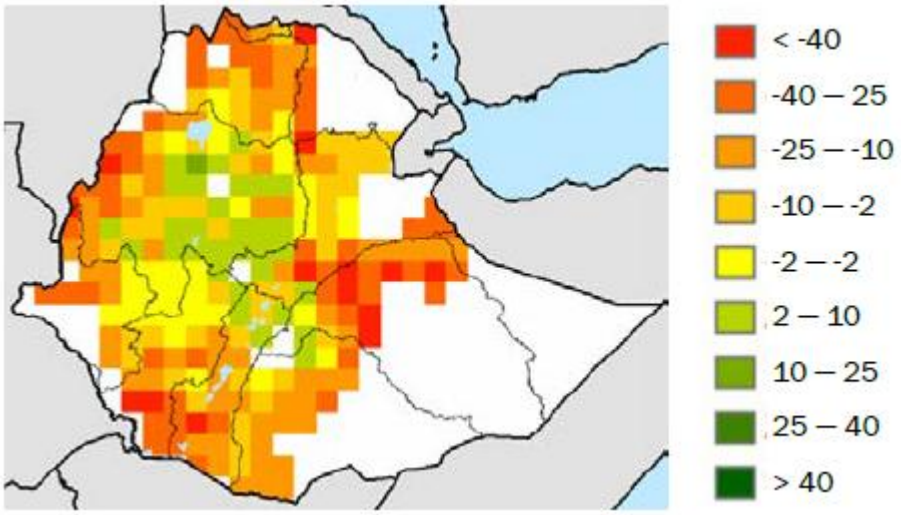


Figure 3-16 - Yield changes for Teff, 2001-2020 to 2041-2060 under climate change (The World Bank Group, 2024)

Crop yields are also indirectly affected by changes in land erosion due to climate change and the resulting topsoil loss. Generally, increased rainfall results in increased topsoil loss. These impacts are not included in the results presented in Figure 3-16.

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

3.4.2 Wheat

The climate risk profile developed by (AGRICA, 2020) provides an overview of projected climate parameters and related impacts on different sectors in Ethiopia until 2080, under different climate change scenarios (called Representative Concentration Pathways, RCPs). RCP2.6 represents the low emissions scenario in line with the Paris Agreement; RCP6.0 represents a medium to high emissions scenario. Wheat yields (as with other crops) rely on water availability and are vulnerable to drought due to their rainfed nature. At present, the uncertainty surrounding water availability projections contributes to a high level of uncertainty in drought forecasts. Under the RCP6.0 scenario, the probable range of drought exposure for the national cropland area per year expands from 0.04–1.4% in 2000 to 0.04–3.9% in 2080. This translates to a threefold increase in drought exposure over this period. As such, wheat is expected to experience a slight decline under both RCP2.6 and RCP6.0 scenarios (Figure 4-18). While there may be minimal change in national-level wheat yields, it is

anticipated that certain regions will experience more pronounced increases while others may see more significant decreases due to the impacts of climate change (AGRICA, 2020).

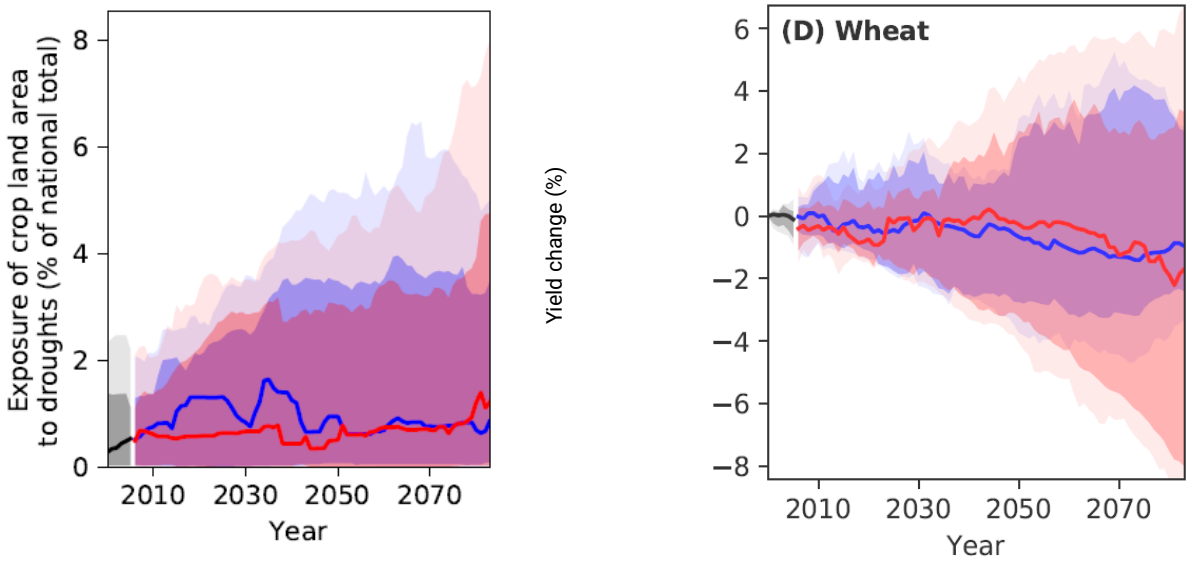


Figure 3-17 - Projections of drought and crop yield changes for wheat in Ethiopia for different GHG emissions scenarios assuming constant land use and agricultural management, relative to the year 2000 (AGRICA, 2020)

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

3.5 RISK ASSESSMENT FOR POST-HARVEST VALUE CHAIN STAGES

3.5.1 Teff

Our assessment of climate change risks to the Teff value chain in Ethiopia highlights, in terms of hazards, temperature fluctuations, including rises in average temperature and more frequent extremely hot days exceeding 35°C. Additionally, heavy precipitation events, flooding (both pluvial and fluvial), landslides, and wildfires are also significant hazards. Cyclones present a slightly lower threat in this context.

Ethiopian stakeholders at the national and local levels underscored that for the teff value chain, climate hazards that pose the most substantial risk at harvest and during the post-harvest stages are **heavy or variable rainfall (excessive or erratic), flooding, and high temperatures (extreme heat)**.

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

Table 3-6 - Top three climate change hazards identified for Ethiopia's Teff 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
National Attendees and Representatives (Addis Ababa)	• Heavy or variable (excessive or erratic) rainfall causing shattering and lodging but also making harvest difficult; • Flooding causing lodging; • High temperatures (extreme heat)	• Heavy or variable (excessive or erratic) rainfall causing threshing losses, Flooding causing storage losses; • High temperatures (extreme heat) causing increased incidence of diseases, storage pests, aflatoxins	• Heavy or variable (excessive or erratic) rainfall; • Flooding; • Delays in transport and marketing • High temperatures (extreme heat); reduced product quality
Local Attendees and Representatives (Addis Ababa)	• Heavy or variable (excessive or erratic) rainfall; • Flooding; • High temperatures (extreme heat)	• Heavy or variable (excessive or erratic) rainfall; • Flooding; • High temperatures (extreme heat)	• Heavy or variable (excessive or erratic) rainfall; • Flooding; • High temperatures (extreme heat)

Various factors increase vulnerability within the Teff value chain, such as a substantial rural population heavily reliant on agriculture, limited availability of climate resilient varieties, teff-focused technologies and practices, inadequate irrigation infrastructure resulting in dependence on rainfed agriculture, and high levels of poverty and unemployment. It's essential to recognize that these vulnerability factors extend beyond the post-harvest stages of the Teff value chain and affect the agricultural sector more broadly.

National and local strengthened the understanding of vulnerability in the teff value chain, indicating that the principal drivers of vulnerability in Ethiopia's teff value chain – at harvest and during post-harvest stages – are: **lack of access to or knowledge of modern (non-traditional) harvesting and threshing methods; reliance on manual rather than mechanized techniques; limited knowledge and capacity of smallholder farmers; limited or poor access to market information; and limited or poor access to credit.**

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

Table 3-7 - Top three climate change vulnerability factors identified for Ethiopia's Teff 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
National Attendees and Representatives (Addis Ababa)	• Lack of/limited access to modern (non-traditional) harvesting and threshing; • High labour demand • Traditional threshing methods leading to grain contamination with sand and other, causing impurities • Limited knowledge and capacity of smallholder farmers;	• Lack of/limited access to modern (non-traditional) harvesting and threshing • Limited access to drying machinery, high humidity leading to change in color and quality • Poor storage facility, losing product market quality • Limited knowledge and capacity of smallholder farmers;	• Limited or poor access to market information; Limited or poor access to credit; • Limited knowledge and capacity of smallholder farmers

Stakeholder Workshop Location	Harvesting Processes	Post-Harvest Handling and Storage	Processing, Transport, and Logistics
	• Reliance on manual (rather than mechanized) techniques	• Reliance on manual (rather than mechanized) techniques	
Local Attendees and Representatives (Addis Ababa)	• Displacement and forced migration to leave land for government preferred value chains (e.g. irrigated wheat); • Low socio-economic capacity and limited knowledge of smallholder farmers; • Reliance on manual (rather than mechanized) techniques	• Displacement and forced migration; • Low socio-economic capacity and limited knowledge of smallholder farmers; • Reliance on manual (rather than mechanized) techniques	• Limited or poor access to market information; • Limited or poor access to credit; • Limited knowledge and capacity of smallholder farmers

A key factor in terms of **exposure** is the share of cropland area under Teff. The current level of financial losses in the Teff harvest and post-harvest value chain in Ethiopia is regarded as High, with total yield loss of about 25 to 30%.

Overall, in our comparative climate change risk assessment, quantitatively, the risk level of the Teff value chain in Ethiopia scored: 26.442 out of 125 (Table 3-8), putting it at rank 7 of the 14 crop value chains similarly assessed.

Table 3-8 - 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	***Teff***	Maize	Maize	Maize	Maize	Maize
	33.92	***26.44***	26.40	73.31	37.33	26.69	47.90
	Rice	***Wheat***	Beans	Groundnut	Rice	Beans	Soybeans
	22.23	***35.25***	13.20	13.84	17.77	25.91	23.58

The optimal temperature range for teff growth was determined to be between 13.2 °C and 25.2 °C (Yumbya, de Vaate, Kiambi, Kebebew, & Rao, 2014)**.** Presently, average temperatures remain within this ideal range. However, if the current trend of rising temperatures persists, it is anticipated to surpass the critical threshold for optimal teff growth before 2050. This average temperature increase is projected to adversely affect teff cultivation, leading to decreased yields and exacerbating food insecurity concerns (Tembo, 2018).

Reduced annual rainfall adversely impacts teff production (Tembo, 2018). (Yumbya, de Vaate, Kiambi, Kebebew, & Rao, 2014) observed that the optimal rainfall range for teff growth is between 600-1900 mm. Presently, rainfall conditions conducive to teff growth are generally satisfactory despite occasional droughts (e.g., in 1990, 1999, 2000, 2014). However, if annual rainfall continues to decrease, teff growth is projected to reach a critical threshold before 2040.

Model results show that 38% of the country is suitable for successful teff production under current conditions. By 2050, projections forecast a 4% decrease in teff suitability in Ethiopia under RCP2.6 and a 7% decrease under RCP8.5 (Murken, Gornott, & et al., 2020).

Teff, being indigenous to Ethiopia, demonstrates resilience against many field pests and diseases common in other cereal crops, with the exception of the shoot fly. Its ability to withstand storage for up to 10 years without damage further exemplifies its durability. Particularly in drought years, Teff's short-duration varieties offer a critical food source, maturing within three months, when longer-duration crops like sorghum and maize may fail due to water scarcity. Drought poses a significant threat to smallholder agriculture, as evidenced by the 1997/98 drought which resulted in a 25% drop in cereal production. The major drought of 2015, exacerbated by El Niño, delayed rainfall, leading to sorghum planting setbacks, which contributed to a 14% decrease in cereal production (Orr, et al., 2017).

In drought-prone areas, Teff is crucial for adaptive farming. Teff is predominantly grown in poorly drained vertisols which are not suitable to grow other crops. Farmers adjust planting based on rainfall timing: April rains prompt long-duration sorghum planting for the October harvest, while delayed rains in June/July favour shorter-duration sorghum. Teff, usually sown during this time, matures in 3-5 months. If sorghum fails, Teff sales fund sorghum purchases, showcasing Teff's unmatched risk management potential in times of drought.

While direct attribution of climate change to post-harvest losses of Teff in Ethiopia 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 12.55 % of the Teff harvest in Ethiopia was lost as dry-weight loss based on decadal data from 2013 through 2022 (APHLIS, 2024). Of the various post-harvest value-chain stages (per APHIS, these are: harvesting/field drying; further drying; threshing and shelling; winnowing; transport from field; household level storage; transport to market; and market storage), the three stages where the largest average volume of Teff losses occurred in Ethiopia (in decreasing order over the decade) are:

1. **Harvesting and field drying** – an average annual loss of 3.5 % of the crop;
2. **Threshing and shelling**– an average annual loss of 3.5 % of the crop;
3. **Market storage** – an average annual loss of 2.7 % of the crop.

Together, these three stages represent an average annual loss of 77.3% of the total losses in the post-harvest Teff value chain in Ethiopia. In each of these three stages, climatic factors are highly relevant, given the manner in which temperature, moisture, and humidity, and the prevalence of pests and plant diseases (themselves temperature-sensitive) cause damage to the harvested teff.

Delayed harvesting extends pre-harvest field drying, which can aid preservation but raises the risk of shattering before harvest, incomplete straw harvesting, damage from unseasonal rain, and animal (bird) attacks (Table 3-9). Conversely, harvesting before maturity poses the risk of low-quality Teff grain and potential loss due to mould development, ultimately leading to product decay (Tiguh, Delele, Ali, Kidanemariam, & Fenta, 2024).

Table 3-9 - Preliminary screening of losses in the Teff supply chain in Ethiopia (adapted from (Tiguh, et al., 2024))

Supply chain stage	Activities in the supply chain stage	Quantitative loss at each activity (%)	Quantitative loss at each stage (%)	Remark
Production (farm)	Harvesting	5.6	25	Shattering, weather conditions
	Piling/field storage	6.3		Damage by termites and animals, Rain (moisture)
	Threshing	7.7		Scattering, Contamination with soil and animal wastes, consumption by trampling animals
	Storage at the farmer's level	3.2		Rodents
	Farmer's transportation	2.2		Leakage, Loading, and unloading
Market	Wholesalers	8.5	15.9	Spillage
	Retailers	7.4		Spillage

With climate change projected to exacerbate these factors, through rising temperatures, more erratic and heavy rainfall events, and through the growing risk of floods and heatwaves in Ethiopia, ***these stages of the Teff 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 Teff value chain are still largely linked to on-farm activities such as harvesting and field drying, piling and field storage, and threshing and shelling it is fair to surmise that the areas in Ethiopia where Teff is farmed are the dominant geographical locations for these losses, at these stages. Based on the map of Teff growing areas in Ethiopia (Figure 3-18) (Orr, et al., 2017) Highland regional States such as Amhara and Oromia may be prioritized for climate-responsive, risk-reduction interventions.

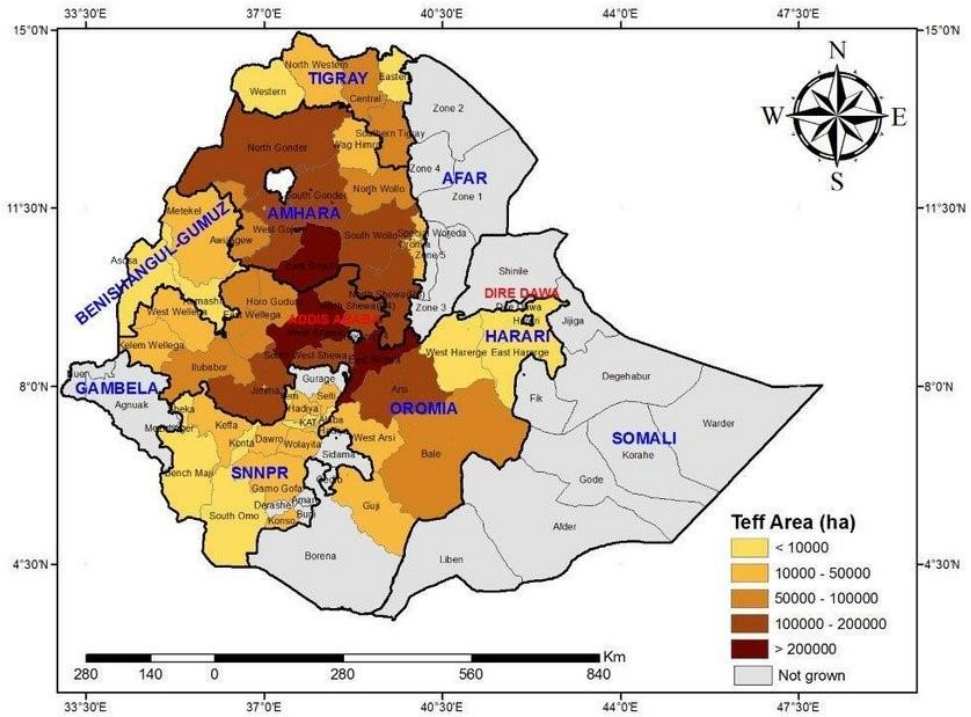


Figure 3-18 - Distribution of teff in Ethiopia (Yumbya, de Vaate, Kiambi, Kebebew, & Rao, 2014)

Stakeholder workshops in Ethiopia 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 teff value chain, particularly during harvest and post-harvest stages. Insights and guidance from stakeholders suggest that the priority locations that should be the focus of RE-GAIN's post-harvest loss-reduction climate change solutions are:

- Oromia: Arsi; West Arsi; East Shoa (East Shewa)
- Amhara: East Gojjam; North Shoa (North Shewa)
- Central Ethiopia / Southern nations and people: Hadiya Zones; Gurage Zones

3.5.2 Wheat

Our evaluation of climate change risks to the wheat value chain in Ethiopia underscores, in terms of hazards, temperature fluctuations, marked by increased average temperatures and more frequent days exceeding 35°C. Additionally, significant hazards include heavy precipitation events, both pluvial and fluvial flooding, landslides, and wildfires, with cyclones posing a slightly lower threat.

Ethiopian stakeholders at the national and local levels affirmed that for the wheat value chain, climate hazards that pose the most substantial risk at harvest and during the post-harvest stages are **heavy or variable rainfall (excessive or erratic), flooding, high temperatures (extreme heat), and contamination by pests and diseases - particularly mould, mycotoxin and aflatoxin**.

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

Table 3-10 - Top three climate change hazards identified for Ethiopia's wheat 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
National Attendees and Representatives (Addis Ababa)	Heavy or variable (excessive or erratic) rainfall; Flooding; high temperatures (extreme heat)	Heavy or variable (excessive or erratic) rainfall; Aflatoxin, pest contamination; high temperatures (extreme heat)	Heavy or variable (excessive or erratic) rainfall; Aflatoxin, pest contamination; high temperatures (extreme heat)
Local Attendees and Representatives (Addis Ababa)	Heavy or variable (excessive or erratic) rainfall; Flooding; high temperatures (extreme heat)	Heavy or variable (excessive or erratic) rainfall; Aflatoxin, pest contamination; high temperatures (extreme heat)	Heavy or variable (excessive or erratic) rainfall; Aflatoxin, pest contamination; high temperatures (extreme heat)

Numerous factors contribute to **vulnerability** within the wheat value chain, including a sizable rural population heavily dependent on agriculture, inadequate irrigation infrastructure leading to reliance on rainfed agriculture, and elevated levels of poverty and unemployment. It's crucial to note that these vulnerability factors extend beyond the post-harvest stages of the wheat value chain and impact the broader agricultural sector.

National and local strengthened the understanding of vulnerability in the wheat value chain, indicating that the principal drivers of vulnerability in Ethiopia's wheat value chain – at harvest and during post-harvest stages – are: **lack of access to or knowledge of modern (non-traditional) harvesting and threshing methods; reliance on manual rather than mechanized**

techniques; limited knowledge and capacity of smallholder farmers; limited or poor access to market information; and limited or poor access to credit.

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

Table 3-11 - Top three climate change vulnerability factors identified for Ethiopia's wheat 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
National Attendees and Representatives (Addis Ababa)	• Lack of/limited access to modern (non-traditional) harvesting and threshing; • Limited knowledge and capacity of smallholder farmers; • Reliance on manual (rather than mechanized) techniques • Shattering due to untimely rains and loss during harvest • Contamination by fungal diseases , and multiplying in storage	• Lack of/limited access to modern (non-traditional) harvesting and threshing; • Limited knowledge and capacity of smallholder farmers; • Reliance on manual (rather than mechanized) techniques • Shrinkage of grain due to early harvest due to untimely rains • Yield Loss during threshing due to humid weather, that makes separating grain from stover difficult • Pests multiplying in stores due to high temperature and cause both quality and quantity loss	• Limited or poor access to market information; • Limited or poor access to credit; • Limited knowledge and capacity of smallholder farmers
Local Attendees and Representatives (Addis Ababa)	• Supply chain disruptions • Low socio-economic capacity and limited knowledge of smallholder farmers; • Reliance on manual (rather than mechanized) techniques	• Supply chain disruptions • Low socio-economic capacity and limited knowledge of smallholder farmers; • Reliance on manual (rather than mechanized) techniques	• Limited or poor access to market information; • Limited or poor access to credit; Supply chain disruptions.

Regarding **exposure**, the proportion of cropland area dedicated to wheat cultivation is a key factor. Currently, the financial losses in the wheat post-harvest value chain in Ethiopia are considered very low.

Overall, in our comparative climate change risk assessment, quantitatively, the risk level of the wheat value chain in Ethiopia scored: 35.256 out of 125 (Table 3-12), putting it at rank **4** of the 14 crop value chains similarly assessed.

Table 3-12 - 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

Wheat is the third most dominant crop after teff and maize in Ethiopia, growing in temperatures ranging from 14–18 °C (Bouteska, Sharif, Bhuiyan, & Abedin, 2024). This cash crop is being produced by about 35% of smallholder farmers on 17% of the total arable area in Ethiopia, mainly in the highlands. Oromia, Amhara, South Nation Nationality and People, and Tigray are examples of the main regions with high yields of wheat. It is a rabi crop that necessitates a 50–100 cm rainfall. Wheat can be harvested 90-150 days after planting (Murken, Gornott, & et al., 2020).

Only 31% of the land area in the country is suitable for wheat. In this study (Murken, Gornott, & et al., 2020), researchers found that wheat will be most affected by climate change. Its net suitability is projected to decrease by 9% under RCP2.6 and by 12% under RCP8.5 until 2050. The fluctuations in wheat suitability pertain to the collective adaptability of various wheat varieties, including bread wheat, durum, and emmer, cultivated in Ethiopia. Wheat is notably sensitive to heat and water stress prevalent in warmer climates, necessitating specific conditions during various growth stages. Wheat thrives in warm temperatures during the sowing period. However, excessive temperature increases can disrupt the crop's molecular structure, hindering proper maturation. Furthermore, heightened temperatures contribute to decreased groundwater levels, exacerbating dry conditions in historically arid regions. This water scarcity negatively impacts crop cultivation, highlighting the continued reliance on rainfall for harvests and the beneficial correlation between farming activity in Ethiopia and the monsoon season (Bouteska, Sharif, Bhuiyan, & Abedin, 2024).

According to data from the African Post Harvest Loss Information System (APHLIS), an estimated 14.15 % of the wheat harvest in Ethiopia was lost as dry-weight loss in 2022 based on the average decadal data from 2013 through 2022 (APHLIS, 2024). Of the various post-harvest value-chain stages (per APHIS, these are: harvesting/field drying, further drying, threshing and shelling, winnowing, transport from the field, household level storage, transport to market, and market storage), the three stages where the largest average volume of wheat losses occurred in Ethiopia (in decreasing order over the decade) are:

1. According to data from the African Post Harvest Loss Information System (APHLIS), an estimated 14.15 % of the wheat harvest in Ethiopia was lost as dry-weight loss in 2022 based on the average decadal data from 2013 through 2022 (APHLIS, 2024). Of the various post-harvest value-chain stages (per APHIS, these are: harvesting/field drying, further drying, threshing, and shelling; winnowing, transport from the field, household level storage, transport to market, and market storage), the three stages where the largest average volume of wheat losses occurred in Ethiopia (in decreasing order over the decade) are: Household storage level– an average annual loss of 4.8 % of the crop;
2. Harvesting/field drying– an average annual loss of 4.4 % of the crop;
3. Threshing and shelling – an average annual loss of 3.5 % of the crop.

Together, these three stages represent an average annual loss of 89.7 % of the total losses in the post-harvest wheat value chain in Ethiopia.

In each of these three stages, **climatic factors are relevant**, given the manner in which temperature, moisture and 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 through the growing risk of floods and heatwaves in Ethiopia, ***these stages of the wheat 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 wheat value chain are still largely linked to on-farm activities and storage such as harvesting and household storage, it is fair to surmise that the areas in Ethiopia where wheat is farmed are the dominant geographical locations for these losses, at these stages. Based on the map of wheat growing areas in Ethiopia (Figure 3-19) (USDA-IPAD, n.d.), the Regional States of Oromia and Amhara may be prioritized for climate-responsive, risk-reduction interventions.

Since these stages (where the largest share of post-harvest losses happens) of the wheat value chain are still largely linked to on-farm activities and storage such as harvesting and household storage, it is fair to surmise that the areas in Ethiopia where wheat is farmed are the dominant geographical locations for these losses, at these stages. Based on the map of wheat growing areas in Ethiopia (Figure 3-19) (USDA-IPAD, n.d.), the Regional States of Oromia and Amhara may be prioritized for climate-responsive, risk-reduction interventions.

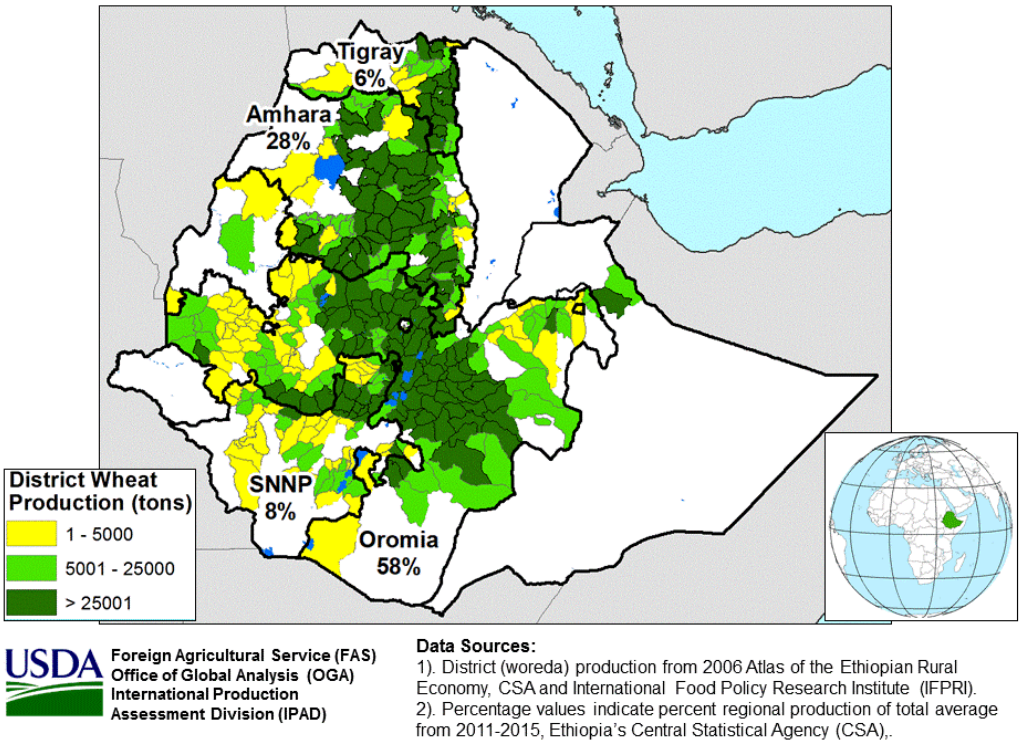


Figure 3-19 - Ethiopia Wheat Production (2011-2016) (USDA-IPAD, n.d.)

Stakeholder workshops in Ethiopia 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 wheat value chain, particularly during harvest and post-harvest stages. Insights and guidance from stakeholders suggest that the priority locations that should be the focus of RE-GAIN's post-harvest loss-reduction climate change solutions are:

- Oromia: Arsi; West Arsi; East Shoa (East Shewa)
- Amhara: East Gojjam; North Shoa (North Shewa)
- Central Ethiopia / Southern nations and people: Hadiya Zones; Gurage
- Zones

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 Teff and Wheat in Ethiopia are presented in Table 3-13.

Table 3-13 - Summary Climate Change Hazard Risk Table for Ethiopia 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
TEFF	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
	Wildfires			
	Landslides			
	Cyclones			
	Sea Level Rise	N/A	N/A	N/A
	OVERALL RISK LEVEL	*HIGH*	*HIGH*	*MODERATE*
WHEAT	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
	Wildfires			
	Landslides			
	Cyclones			
	Sea Level Rise	N/A	N/A	N/A
	OVERALL RISK LEVEL	*HIGH*	*HIGH*	*MODERATE*

Key:

High	
Medium	
Low	

4 Climate analysis - Mitigation

4.1 COUNTRY AND SECTORAL CLIMATE CHANGE EMISSIONS BASELINE

4.1.1 National emissions

Ethiopia presented its National Greenhouse Gas Inventory (GHGI) in their Third National Communication (Ethiopia, 2022) to the United Nations Framework Convention on Climate Change. Energy, and agriculture are the largest emitting sectors at ~24 million tonnes CO_2e as of 2021 (Figure 4-1) (ClimateWatch, 2024). While Ethiopia's national emissions have grown steadily in the last few decades, it still contributes only 0.56% of global emissions (Jones et al., 2024).

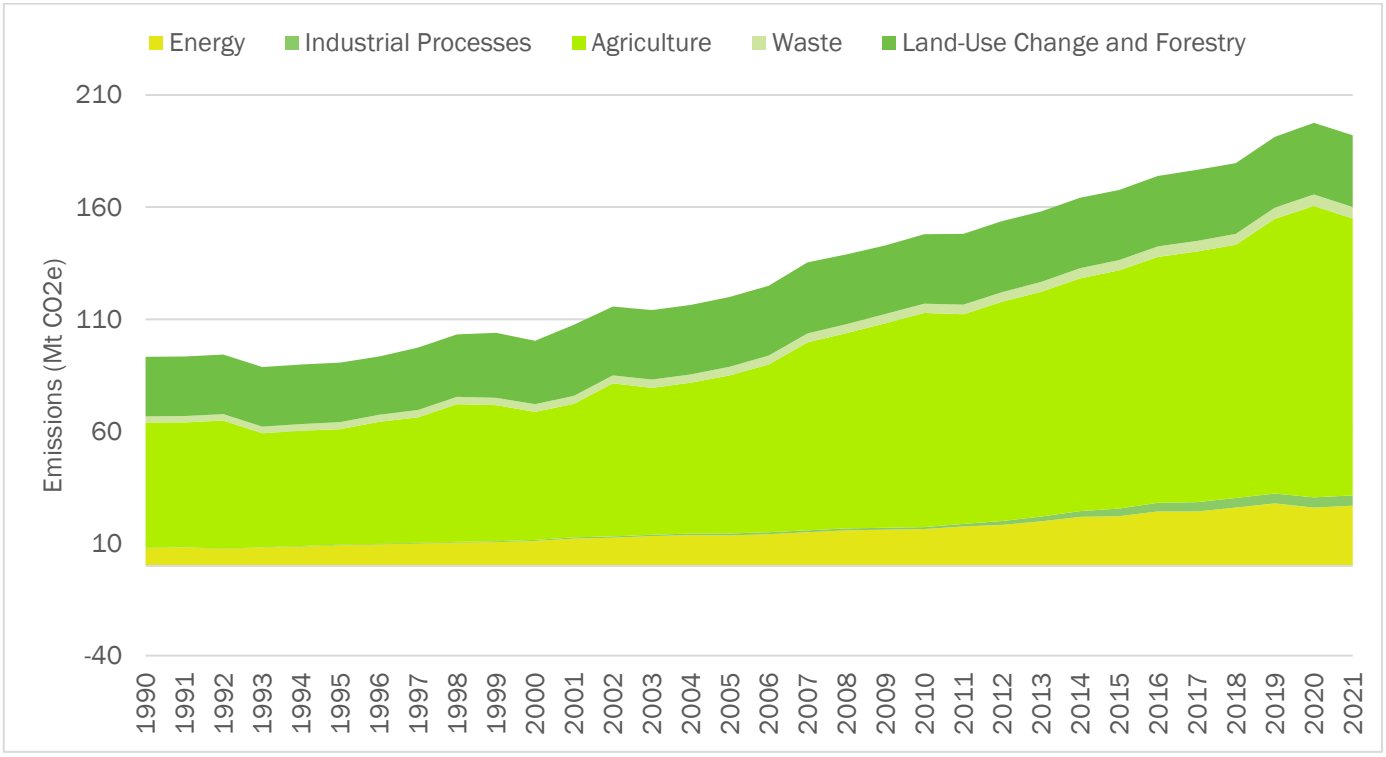


Figure 4-1 - Emissions (all GHG, $MtCO_2e$) across all sectors (total including LUCF) for Ethiopia (ClimateWatch, 2024)

4.1.1.1 Land use change

By using available land use change datasets, we can ascertain that forest cover has remained relatively stable in Ethiopia between 1960 and 2019, with forest loss occurring over ~8% (HILDA+, 2024) **of the land area in AGRA's target regions (see Figure 4-2 below).** Cropland expanded over ~28% of the area in that period (Figure 4-2). Where deforestation occurred between 2001 and 2020, the most common land uses which replaced forest cover were large and small-scale agriculture, pasture, and other land use types Table 4-1 (Masolele et al., 2024).

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

	Addis Ababa	Afar	Amhara	Beneshangul Gumu	Dire Dawa	Gambela	Hareri	Oromia	SNNPR	Somali	Tigray
Large-scale cropland	76.9%	61.5%	41.4%	39.0%	N/A	12.7%	50.0%	10.9%	6.3%	11.7%	36.8%
Pasture	<1%		2.7%	2.0%	N/A	3.5%	33.3%	5.3%	3.7%	57.8%	17.5%
Mining	1.1%	3.8%	<1%	<1%	N/A	1.0%		<1%	<1%	1.0%	3.4%
Small-scale cropland	15.5%	23.1%	42.8%	33.7%	N/A	25.9%	16.7%	76.0%	67.3%	25.8%	31.6%
Roads				<1%	N/A	5.2%		<1%	<1%	1.1%	
Other land with tree cover/ Regrowth			1.6%	20.9%	N/A	46.9%		4.0%	13.3%	1.7%	<1%
Plantation forest	2.2%		<1%	<1%	N/A	<1%		<1%	1.0%		
Coffee				<1%	N/A	1.0%		<1%	<1%		
Settlement	4.0%		9.0%	<1%	N/A	3.0%		1.4%	1.2%	<1%	9.4%
Tea plantation					N/A			<1%	1.1%		
Water		11.5%	1.3%	1.0%	N/A	<1%		<1%	<1%	<1%	<1%
Oil palm				<1%	N/A			<1%	<1%		
Rubber					N/A			<1%	<1%		
Cashew				<1%	N/A	<1%		<1%	<1%		
Cocoa			<1%	1.3%	N/A	<1%		<1%	2.9%		

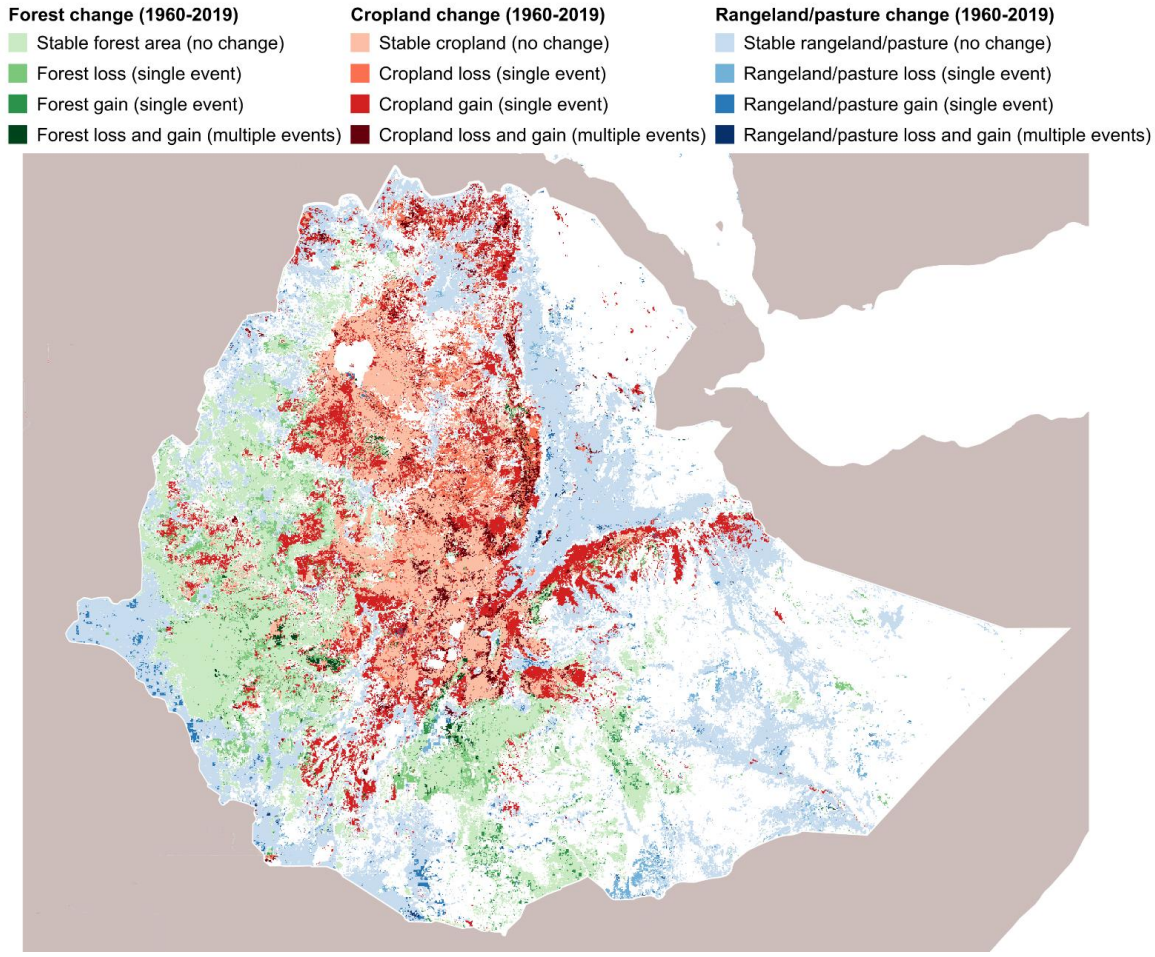


Figure 4-2 - Change in cover for land use categories forest, rangeland/pasture and cropland in AGRA target regions across Ethiopia between 1960 and 2019 (HILDA+, 2024)

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 wheat (Poore & Nemecek, 2018). Farm activities account for up to 82% of emissions from wheat (Figure 4-3). Losses account for a significant proportion of emissions (Figure 4-3), particularly in smallholder value chains.

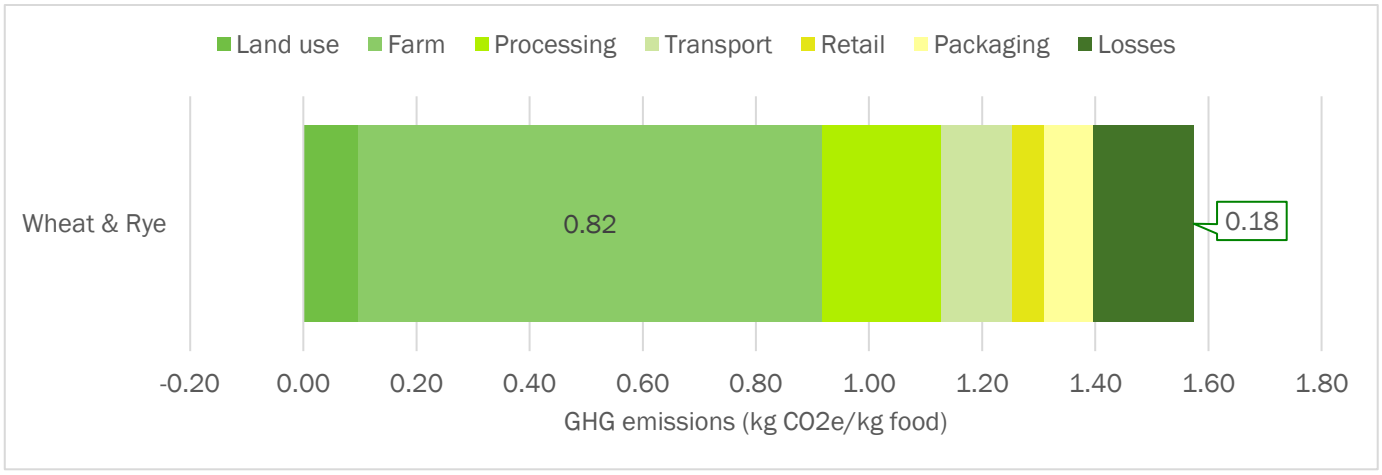


Figure 4-3 - Average GHG emissions (kg CO_2e/kg food) for agricultural commodities across value chains (Poore & Nemecek, 2018)

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

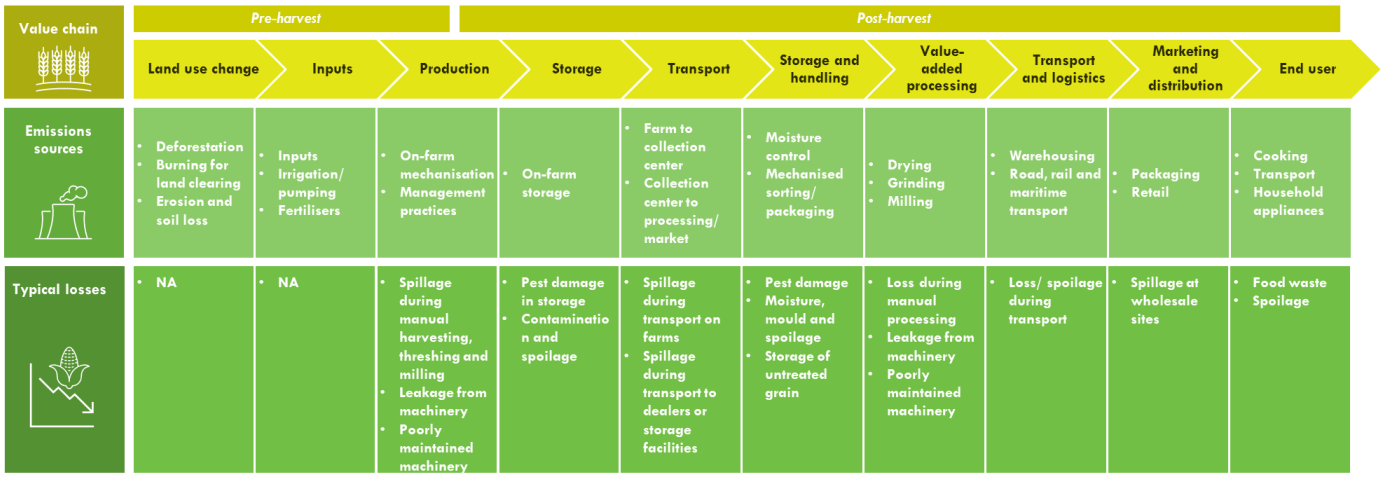


Figure 4-4 - Typical sources of emissions and food losses across agricultural value chains (Report Author's Analysis)

On-farm post-harvest losses resulting from climate impacts, inefficient processing practices, poor storage conditions, pests and spoilage present a loss of income to smallholder farmers, as well as affecting household food security. To compensate for post-harvest losses, farmers are likely to expand their agricultural lands, resulting in 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, soil nutrients 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 but the energy lost to produce the fertilizer used.

4.2.2 Post-harvest losses per crop

4.2.2.1 Wheat

On-farm post-harvest losses in the wheat value chain occur largely as a result of lodging, threshing and inefficient household storage practices (Table 4-2). The largest reported losses occur during this phase, estimated at 4.8% of total production (Table 4-2). Further analysis is discussed in Chapter 5.

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

Value chain stage	Losses (%)	Cause(s)	Notes on loss values	Reference
Harvesting, field drying	4.4%	N/A		

Threshing/ shelling	3.5%	N/A	No data on losses during the drying stage for teff or wheat could be found for Ethiopia, or other African countries on either APHILIS or the FAO FLWD. A loss value of 2% was therefore proposed as a reasonable assumed estimate based on the range of losses during the drying stage available for other crops and countries (1.8% to 4%).	(APHLIS, 2024) (Boxall, 1998) (Dessalegn, et al., 2014) (FAO Food loss and waste database, 2024)
Winnowing	N/A	N/A		
Drying	2.0%	N/A		
Transport to farm	2.5%	N/A		
On-farm storage	4.8%	Losses mostly attributable to moisture, rodents, and spillage. Typically grown at higher altitudes, where insect activity is low and storage periods are short (3-4 months).		
Transport to market	2.5%	N/A		

4.2.2.2 Teff

On-farm post-harvest losses in the teff value chain occur as a result of shattering, lodging, threshing winnowing and inefficient harvesting and threshing practices, as well as poor storage practices. The largest reported losses occur during harvesting and threshing, estimated at up to 3.5% of total production (Table 4-3). Further analysis is discussed in Chapter 5.

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

Value chain stage	Losses (%)	Cause(s)	Notes on loss values	Reference
Harvesting, field drying	3.5%	Poor harvesting techniques	No data on losses during the drying stage for teff or wheat could be found for Ethiopia, or other African countries on either APHILIS or the FAO FLWD. A loss value of 2% was therefore proposed as a reasonable assumed estimate based on the range of losses during the drying stage available for other crops and countries (1.8% to 4%).	(APHLIS, 2024) (Tiguh, Delele, Ali, Kidanemariam, & Fenta, 2024) (Boxall, 1998) (FAO Food loss and waste database, 2024)
Threshing/ shelling	3.5%	N/A		
Winnowing	2.5%	Wind scattering		
Drying	2.0%	N/A		
Transport to farm	2.5%	N/A		
On-farm storage	0.3%	Storage insecticides rarely available outside major towns. Farmers will store treated grain for longer periods to benefit from seasonal price rises.		
Transport to market	1.0%	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 for Ethiopia could amount to 959 809 tCO_2e for teff and 546 712 tCO_2e for wheat, based on smallholder production values (Figure 4-5, Table 4-4).

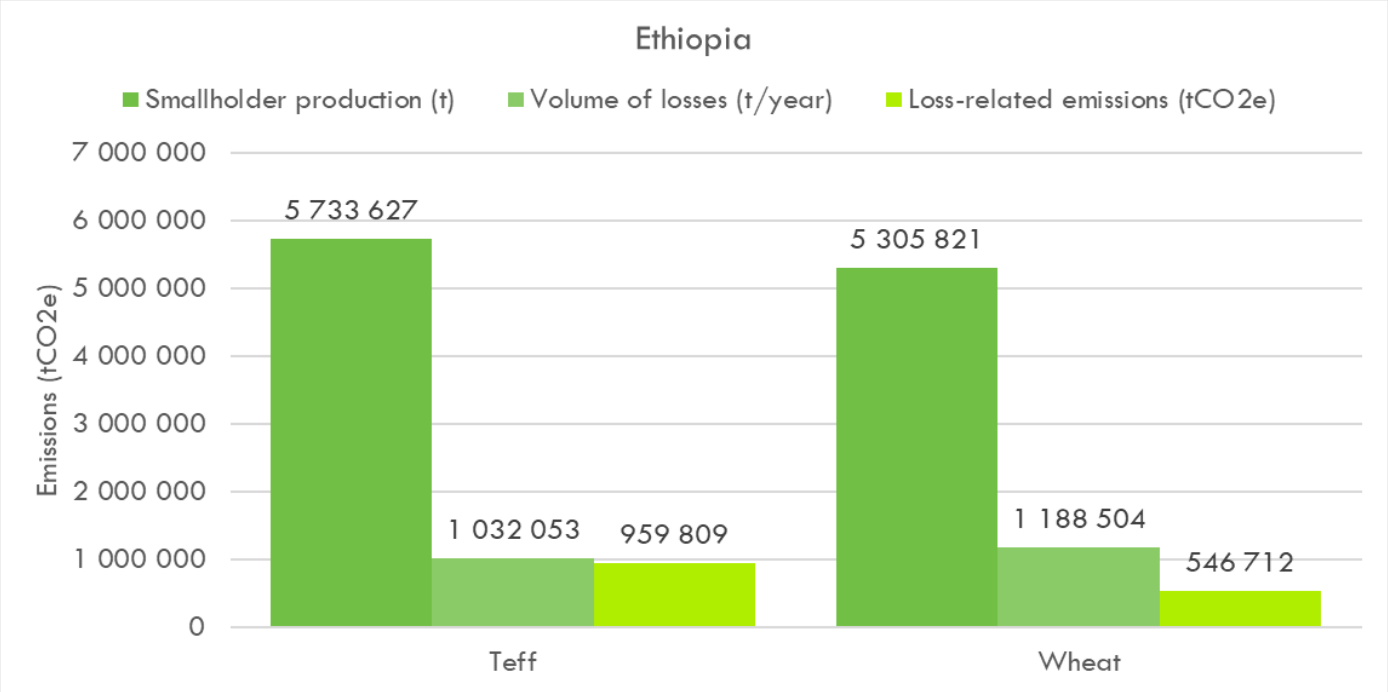


Figure 4-5 – Estimated losses and emissions across agricultural value chains for key commodities

A note on the calculation methodology: Using the total maximum losses possible under the loss scenarios presented in the tables above, a possible total loss (%) per commodity can be calculated, as presented in Table 4-4 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, although they are likely to be understating the food losses for the crop based on qualitative reporting on the topic.

Table 4-4 - Estimated emissions (t CO_2e/t food) calculated using total maximum losses per commodity, total national annual smallholder production (tonnes) and emissions factors for food loss emissions (Porter et al., 2016)

Country	Crop	Smallholder production (t)	Loss rate (%)	Volume of losses (t/year)	Loss-related emissions (tCO2e)
Ethiopia	Teff	5 733 627	18%	1 032 053	959 809
	Wheat	5 305 821	22%	1 188 504	546 712
Total		**11 039 447**	**40%**	**2 220 557**	**1 506 521**

4.3 COUNTRY AND SECTORAL CLIMATE CHANGE EMISSIONS PROJECTIONS

The GHG inventory developed by Ethiopia provides projected emissions to 2030 for key sectors under business-as-usual (BAU) and alternative scenarios, which are also used as part of the Nationally Determined Contributions (NDCs). The BAU emissions projections for Ethiopia as stated in the updated NDC (Federal Democratic Republic of Ethiopia, 2021) are provided below (Figure 4-6, see also Figure 4-1 above). Emissions from managed soils, which include agricultural soils, are projected to increase by 2030 under the BAU emissions scenario, reaching 11 $MtCO_2e$. Likewise, in the land use change and forestry (LUCF) sector, emissions are projected to rise between 2020 and 2030, reaching 140.2 $MtCO_2e$ by 2030 (Federal Democratic Republic of Ethiopia, 2021).

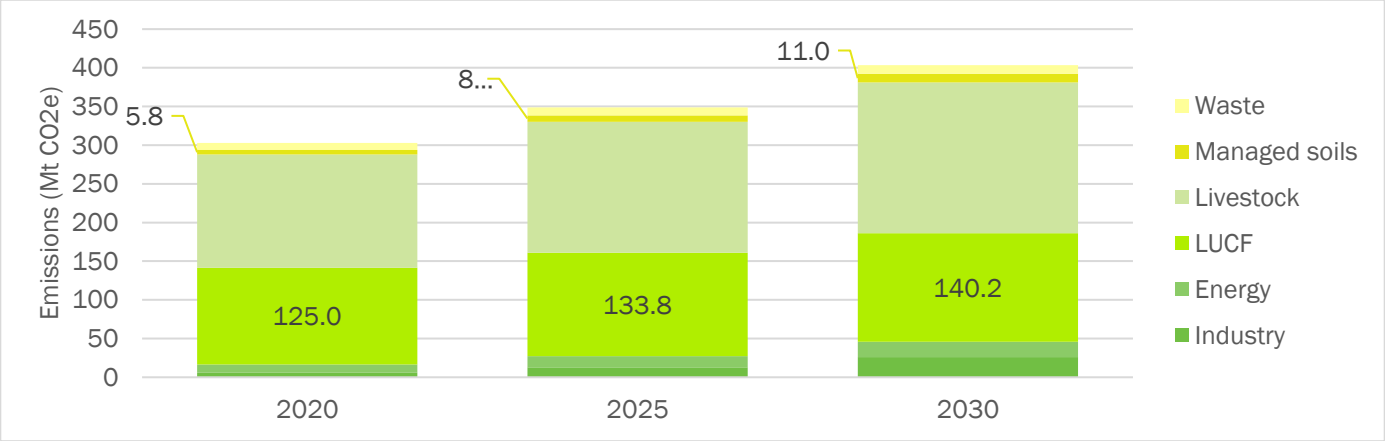


Figure 4-6 - Projected emissions across key sectors in Ethiopia (Federal Democratic Republic of Ethiopia, 2021)

4.4 CROP VALUE CHAINS CLIMATE CHANGE EMISSIONS PROJECTIONS

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

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

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

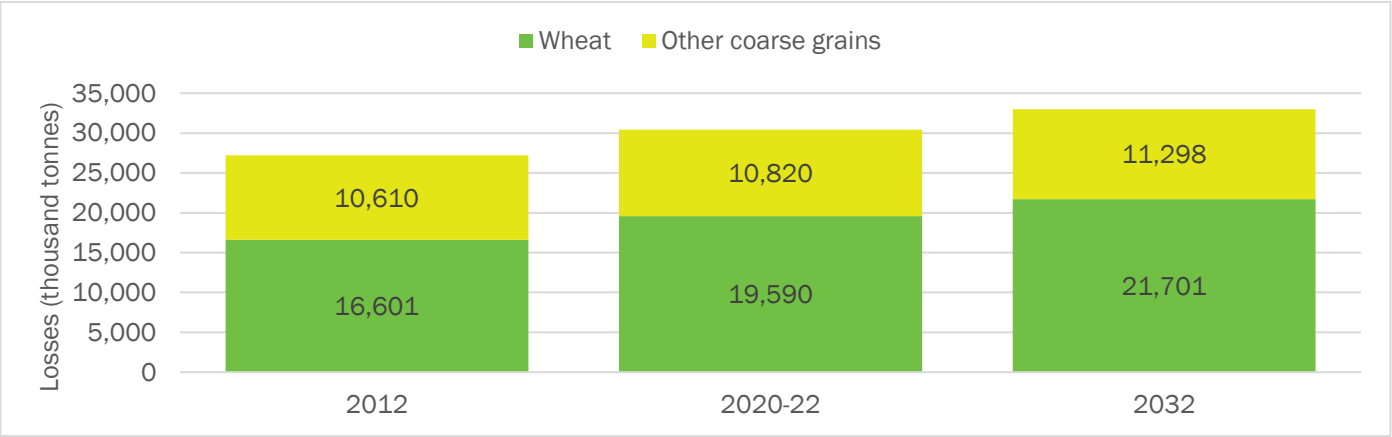


Figure 4-7 - Projected losses across global agricultural value chains for key commodities towards 2032 (OECD & FAO, 2023)

By using available estimates of losses as presented in Table 4-4 above, we can make use of the projected estimates for crop yields and harvested area as presented in the OECD-FAO Agricultural Outlook 2023–2032 (OECD & FAO, 2023) to calculate potential post-harvest losses and associated emissions for 2032. In Table 4-5 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, 2023) provides projected estimates of changes in production, yields and harvested area for key commodity groups across SSA. By using the data available from Table 4-4 and its sources, the OECD & FAO (OECD & FAO, 2023) 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 (t CO_2e) for the year 2032 calculated using projected losses per commodity, total smallholder annual production (tonnes) and emissions factors for food loss emissions (Porter et al., 2016)

Country	Crop	Projected production 2032 (t)	Projected losses 2032 (t/year)	Projected loss-related emissions 2032 (tCO2e)
Ethiopia	Teff	6 622 860	1 192 115	1 108 667
	Wheat	5 641 858	1 263 776	581 337
Total		**12 264 718**	**2 455 891**	**1 690 004**

Without intervention, emissions related to post-harvest losses on smallholder farms in Ethiopia are expected to increase by between ~6% and ~16% (Figure 4-8). **For Ethiopia, this could amount to 581 337 tCO_2e for wheat and 1 108 667 tCO_2e for teff by 2032 (Table 4-5).** This presents the minimum expected losses as climate change is likely to exacerbate these numbers.

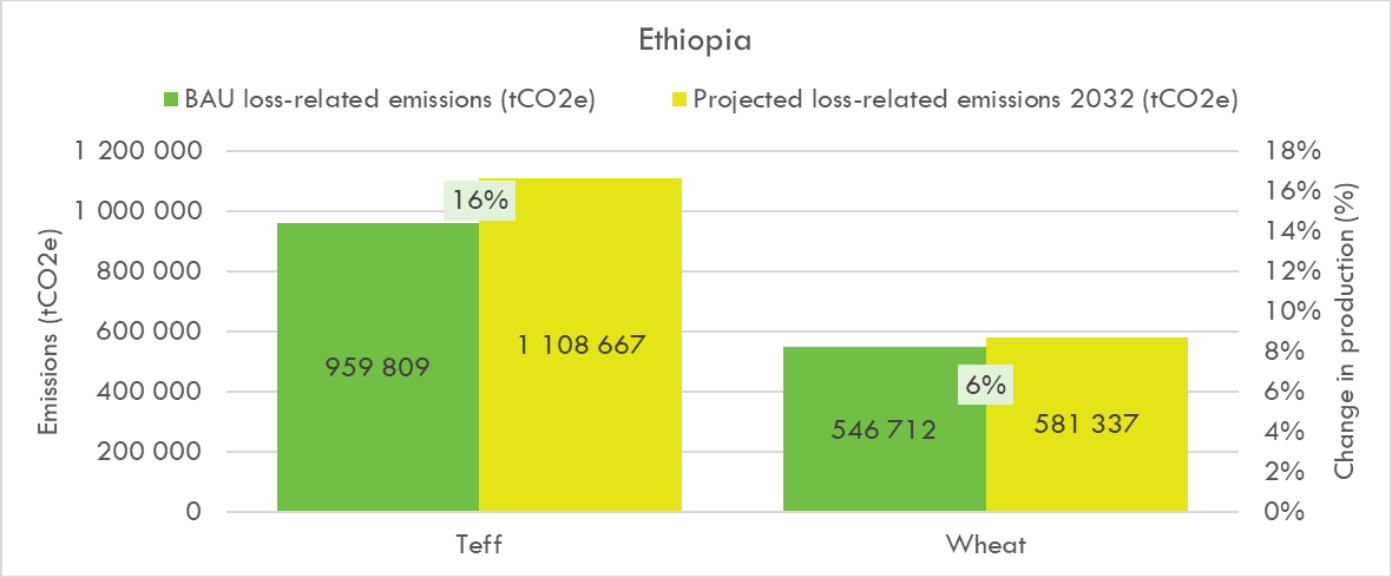


Figure 4-8 - Estimated emissions from post-harvest losses in 2022 and 2032 for key crops in Ethiopia, percentage values indicate projected increase in emissions

5 Design of Food Loss Reduction Solutions

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

5.1.1 Teff

Teff is a fundamental crop in Ethiopia and Eritrea, primarily utilized for making *injera*, a flatbread consumed with most meals (Laterite, 2021). In 2011, teff products made up 12% of Ethiopia's food expenditures, underscoring its importance as the country's principal cereal crop. Teff cultivation covers roughly 20% of Ethiopia's agricultural land (Tadele, 2021). In the 2013/14 period, national teff production reached 4.4 million tonnes, which is lower than maize (6.5 million tonnes) but higher than wheat (3.9 million tonnes) and sorghum (3.8 million tonnes). The average yield for teff was 1.46 tonnes per hectare, while maize yielded 3.25 tonnes per hectare (Laterite, 2021).

Teff is the most commercialized crop, with around 30% sold, generating a total value of 750 million USD in 2013, about half the total value of commercially sold cereal surpluses (Bart Minten, 2016). The Oromia region produces approximately 48% of the national teff, followed by Amhara with 39% (Figure 5-1). Over recent decades, the increase in teff production is attributed to the expansion of land planted with teff.

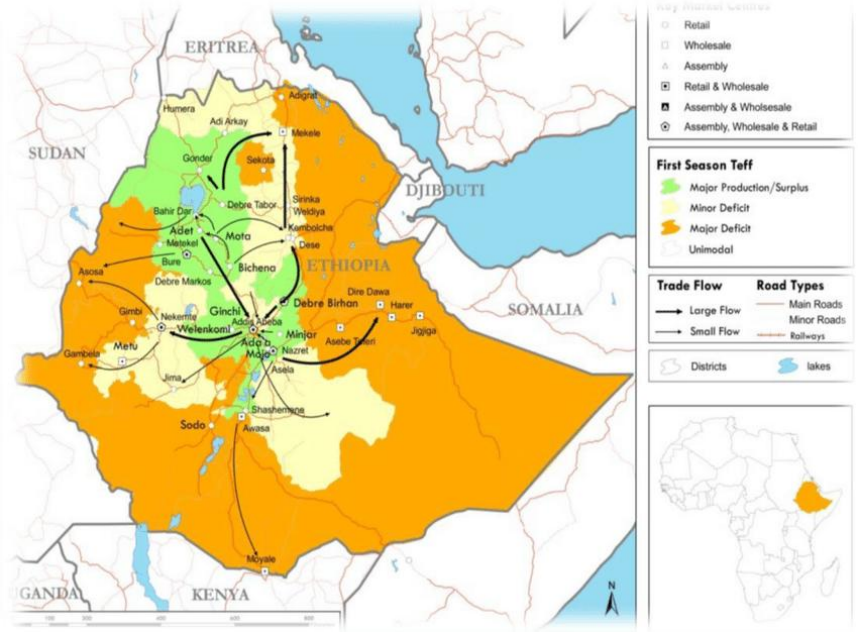


Figure 5-1 - Production and market flow maps of teff (Demeke & Marcantonio, 2013)

Teff is a resilient crop, capable of enduring droughts and floods. It is easily intercropped with other crops and grows in various agro-ecological zones and altitudes (Laterite, 2021) **.** Additionally, teff is less affected by insect pests and diseases, and post-harvest loss is minimal due to low storage insect pest intrusion. Teff is often rotated with onions, chickpeas, common beans, and lentils. It is mainly cultivated using family labour, with some labour exchange or hired labour. Teff seeds come in various colours, ranked by market value: magna (very white), nech (white), sergegna (mixed white and red), and key (red); nech is the most common (up to 52%) (Laterite, 2021). Seeds are mostly broadcasted, though row seeding, which requires less seed, demands more labour.

Farmers harvest teff by cutting with sickles after the crops have matured and dried in the field. The crops are then piled in the field and transported to the threshing area. Some studies indicate that men typically handle harvesting, while others suggest women are more involved (Tiguh E. &., 2024).

Teff requires an average of 40 days to dry between harvesting and threshing (Taffesse A. S., 2018). **Teff is one of the most labour-intensive crops, including during thrashing and winnowing, partly due to limited access to mechanization.** Traditionally, farmers prepare the threshing floor by coating it with cattle dung. Threshing is usually done by oxen trampling the teff, followed by manual seed separation and cleaning using traditional tools. Some farmers have started using modern technologies like multi-crop threshers and seed cleaners.

After threshing, farmers store teff in traditional structures called gotera or gota, synthetic sacks, or traditional 'mounds'. Teff grains can be stored for three to five years without significant losses (Laterite, 2021). Teff straw is rarely sold, typically used for animal feed or construction. Development Agents (DAs) report that most farmers consume less than half of their harvest, selling the remainder (IGNITE & Sasakawa Africa Association, 2022). Teff fetches high prices compared to other grains, making it a valuable cash crop. Prices fluctuate by season and location due to the high consumer preference for teff injera (Hibistu, 2021).

On average, 77% of teff-farming households are male-headed (Laterite, 2021) **.** This aligns with a survey of teff farmers in 16 kebeles, where men led 74% of households. Research shows that teff plots managed solely by women are less productive due to women's limited access to resources and information, and household labour focusing more on plots managed by men (Laterite, 2021).

According to Demeke & Marcadonio (2013), teff is classified as a cereal (n.e.c.) in the FAO and UN Comtrade databases. Table 5-1 provides data on teff's cropping area, production volumes, yields, and its share in national cereal production.

Table 5-1 - Teff's cropping area, production volumes, yields, and the share in the cereal area (FAOSTAT, 2022)

Year	Area (000 ha)	Production (000 tonnes)	Yield (tonnes/ha)	Share in cereal area (%)
2004/2005	2 136	2 026	0.95	28.0%
2010/2011	2 761	3 483	1.26	28.5%
Expansion rate (%)	29,3	72,0		

In terms of teff production per region, the available data is provided in Table 5-2.

Table 5-2 - Regional teff cultivation and production (FAOSTAT, 2022)

Region	Area (ha)	% share of total area planted	Production (Qt)	% share of total production
Tigray	165 804	6.01	2 095 066	6.02
Amhara	1 014 268	36.77	12 791 077	36.75
Oromia	1 289 405	46.74	16 718 025	48.04
SNNPR	265 377	9.62	2 967 594	8.53
Benishangul	23 648	0.86	231 073	0.66
Total/average	2 758 502	100	34 802 836	100

In terms of teff food losses and solutions, different sources and studies provide varying volumes of losses (Table 5-3).

Bart Minten (2016) conducted a survey among 1 200 farmers in five teff zones, representing 38% of the national teff area and 42% of the commercial surplus. Districts with varying productivity levels were selected, and within these districts, random kebeles and large and small producers were chosen. The study analysed self-reported losses by different value chain agents (farmers, wholesalers, and traders), estimating post-harvest losses at an average of 2.2% to 2.3% of total harvested quantities. Losses varied based on storage facilities and on-farm transport methods. These self-reported losses are significantly lower than those reported by other sources.

Regarding post-harvest losses at the farm level, 56% of farmers reported losses averaging 3.1% during traditional animal threshing on dried cow dung floors. However, the overall loss share was only 1.8%. Significant teff storage occurs on-farm: in-house (41%), traditional gotera (35%), and dibignet (mud-plastered storage jars; 22%) (Bart Minten, 2016). The study estimated that only about 0.2% of harvested teff is lost during on-farm storage. Traders, brokers, and urban retailers may lose 0.4% during transactions. Wholesalers lose about 0.3%, and retailers lose around 0.2%.

Other sources report much higher food losses, indicating that food loss data varies between stages in the value chain, regions, and individual households or agents. For further analysis, planning, and impact estimation, the food loss data from column 5 of FAO's Table 1.17 (FAO, 2018) will be used. The FAO uses a standard method for food loss analysis through four progressive stages: screening, survey assessment, sampling and measuring, and finding solutions (FAO, 2014). These figures align with the teff food loss data in the Concept Note.

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

	APHILIS (APHLIS, 2024)	Minten et al., 2016		FAO, 2018	
Harvesting and drying	3.5%			1.9%	5.6%
Threshing and Shelling	3.5%	3.1%	1.8%	2.9%	7.7%
Winnowing	2.5%				
Transport from field	2.5%	0.25%		2.6%	2.2%
Household-level storage	0.3%	2.0%	0.2%	0.5%	3.2%
Transport to market	1.0%	0.4%	0.1%	0.3%	8.5%
Market storage	2.7%	0.7%	0.2%	0.9%	
Transport by wholesalers				0.5%	
Cleaning and handling by wholesalers				0.3%	
Transport by retailers				0.9%	7.4%
Handling by retailers				1.8%	
Overall:	**12.6%**	**2.7%**	**2.5%**	**13.0%**	**41%**

Table 5-4 presents the different steps in the value chain, relevant parameters, and suggested solutions and is largely based on (FAO, 2018).

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

FSC stage/process	% Losses	Economic loss (ETB/ 100kg)	Processes	Cause of losses	Affected stakeholders	Climate aspects	Suggested solutions
Harvesting							
Harvesting	3.5%	95,2	Manual harvesting with sickles/knives (cutting plants at the soil surface)	Shattering of the seeds, head breakage and spoilage resulting from excessive moisture	Farmers	Rains, heat/high temperatures, winds	Trainings/awareness raising on the right time for harvesting (harvest when the moisture content is right)
Stacking / piling	6.3%	107	Stacking/piling in the field after harvesting	Damage by rats, rain, and domestic animals	Farmers	Winds, rains	Stack protection, farmer training
Threshing	3.5%	130,9	Machine threshing, or by using animals walking on the harvest	Contamination of grain with soil/waste of trampling animals. Manual threshing is time consuming and significant losses occur, both qualitative (presence of impurities) and quantitative	Farmers	Winds, rains	Use of machinery, such as mechanical multi-crop thresher with a teff cleaner, that would help to reduce waste, contamination and the work burden on people and animals.
Transportation	2.2%	37,4	Carrying harvest to the farm using available transport types	Spillage of grains when sacks punctured	Farmers	Rains, heat/high temperatures, winds	Training on proper handling of the grain; hermetic and plastic bags
Post-harvest processes (on-farm)							
Farm storage	0.3%	54,4	In silos, bags or baskets, or similar solutions	Rodents, discoloration. poor storage structures	Farmers	Rains, winds	Modern storage facilities, hermetic bags, metal silos, super bags
Transport, logistics, further processing							
Collection from farm	1%		Aggregating and grain collection; transportation to collection centres/ aggregation depot/ markets using vans and trucks of various capacity	Spillage during loading and unloading	Aggregators/ collectors and traders	Rains, winds	
Grading, packing, storage	Not Reported		Sorting, pre-cleaning, packaging	Spillage	Aggregators/ collectors and traders		
Wholesale	8.5%	144,5		Spillage	Wholesalers		Training and use of good bags, specially designed carts to transport farm produce.
Retail	7.4%	125,8		Spillage during loading and unloading, during storage	Retailers		Training, use good bags.

5.1.2 Wheat

Wheat is a vital crop predominantly grown in the Ethiopian highlands at altitudes between 1 500 and 2 700 meters above sea level. As of recent data, wheat cultivation covers approximately 1.9 million hectares, producing around 5.5 million tonnes annually (Senbeta & Worku, 2023) and reported by FAOSTAT as 2.3 million hectares (FAOSTAT, 2022). It provides the flour needed for bread and injera, which are staples across the country. Wheat farming involves substantial use of inorganic fertilizers, herbicides, and, to a lesser extent, fungicides to combat rust diseases. Typically, wheat is planted in the summer before the main rainy season (meher) from June to September and harvested between October and November (Kathryn Bergh, 2012).

There are three primary types of wheat: bread wheat (Triticum aestivum), durum wheat (Triticum turgidum durum), and emmer wheat (Triticum turgidum dicoccoides), with emmer being the wild ancestor of the other two. Bread wheat, which constitutes about half of the planted area, is mainly grown in the highland and semi-highland regions of Oromia, Tigray, and Amhara (Abate D. , 2018). Durum wheat accounts for around 40% of the national wheat area, though specific data is often unclear due to the merging of statistics for bread and durum wheat. A small quantity of emmer wheat is also cultivated, primarily in Oromia (Dibaba, 2019).

While wheat grows in all the regions of Ethiopia, the main production region is Oromia (Figure 5-2), where also high yields are achieved.

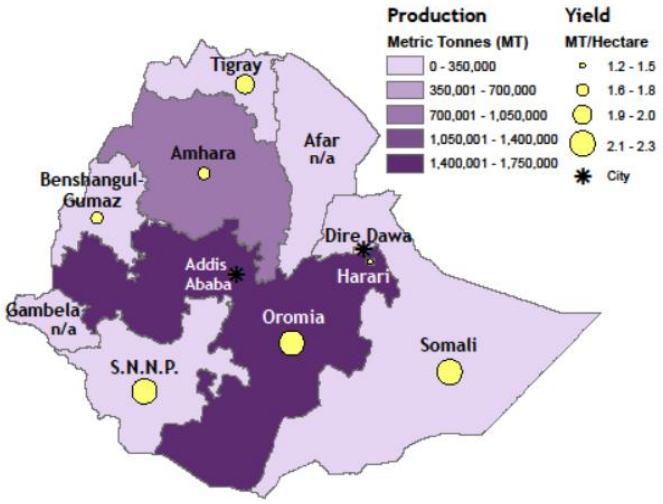


Figure 5-2 - Wheat production and yield by Region ((Kathryn Bergh, 2012)

According to FAOSTAT (2022), wheat cultivation in Ethiopia has been steadily increasing over the past 30 years (1993-2022). Since 2000, the harvested area has doubled from 1.06 million hectares to 2.30 million hectares, and yields have increased by 2.6 times from 1.16 tonnes per hectare to 3.04 tonnes per hectare, resulting in 2022 production levels being 5.67 times higher than in 2000 (FAOSTAT, 2022)). Yearly yields and production volumes have varied slightly due to environmental factors and farming techniques, including increased fertilizer use.

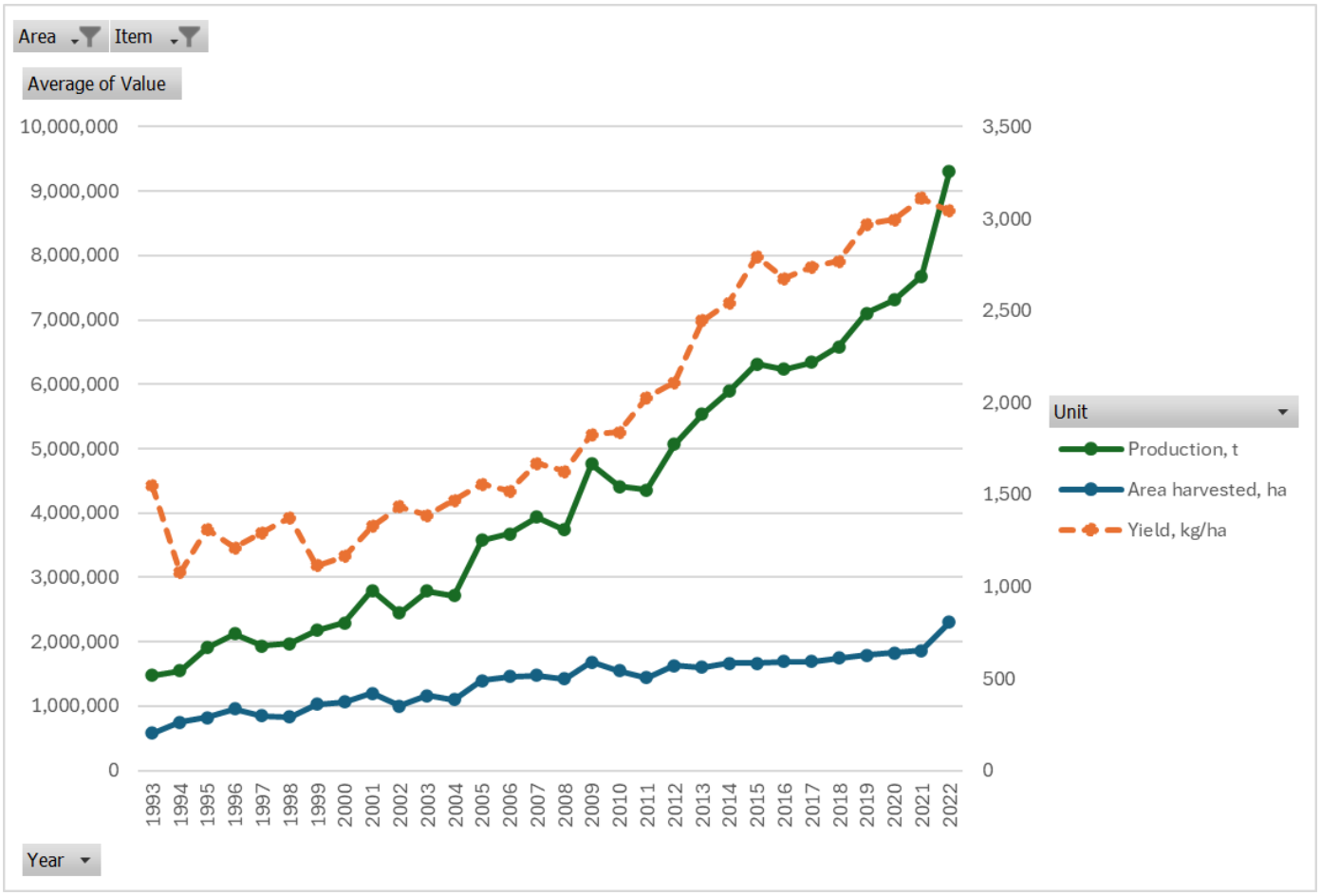


Figure 5-3 - Wheat production, harvest area and annual yields in Ethiopia, 1992-2022 (FAOSTAT, 2022)

Wheat post-harvest food losses have remained relatively stable, averaging around 14.2%, with regional variations from 10.1% to 14.7% (APHLIS, 2022) The estimated food losses at various stages of the value chain are detailed in the Table 5-5.

Table 5-5 - Post-harvest food losses in the different stages in the wheat value chain

Value chain stage	APHLIS (APHLIS, 2024)	Possible causes	Possible solutions
Harvesting/field drying	4.4%	Uncertain weather conditions, shattering	Multi-crop harvesters
Further drying	-		
Threshing and Shelling	3.5%	Threshing method	Improved threshing methods
Transport from field	2.5%		Improved transport solutions
Household-level storage (3-12 months)	4.8%	Humidity (moisture content), insects and rodents	Monitoring moisture and using dryers, hermetic bags, silos, fumigants, pesticides, drying.
Transport to market	1.0%		
Market storage	2.7%		Long-term packaging
Total	**14.2%**		

Ethiopian farmers use various storage control methods to reduce losses, with drying, particularly ground drying using solar radiation, being the most common. Fumigation is the second most popular method to combat insect damage (Tadesse Dessalegn, 2014). Farmers select control methods based on traditional practices, ease of use, material availability, effectiveness, and affordability.

On-farm wheat storage commonly involves fertilizer bags, traditional gotera (storage huts made from local materials), jute bags, polypropylene bags, and warehouses (Tadesse Dessalegn, 2014). Wheat is typically stored for 3-12 months for consumption, later sale, or as seed, during which most losses occur. The main causes of post-harvest loss are humidity (11.75%), insects (11.57%), and rodents (11.12%). Storage losses account for 3% of the total wheat post-harvest loss, largely due to traditional storage methods (Tadesse Dessalegn, 2014).

Average post-harvest losses at the marketing stage range from 0.1% to 2.7% (APHLIS, 2022)**, due to improper handling, spillage, buyer checks, and low grain quality.** Milling or grinding losses at the processors or millers level are about 0.4%, attributed to inefficient milling machines.

Table 5-6 presents the different steps in the value chain, relevant parameters, and suggested solutions.

Table 5-6 - Overview of wheat food losses 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	Manual cutting of mature grains using sickles and knives, or mechanically with threshers or combine harvesters	4.4%	Quantitative losses, shrinkage due to untimely harvest to prevent from untimely rain, increased humidity/ moisture of crops, shattering if the grain is too dry	Farmers	Heat stress for workers/farmers and animals, rains and winds	Capacity building on harvesting techniques and machinery, capacity building and trainings on drying; early warning systems
Threshing	Manual or mechanical, using manual and mechanical threshers	3.5%	Mechanical damage, spillage, grain damage, incomplete threshing and cracking and grain loss for difficulties to separate from the stover	Farmers	Rains, winds, temperature	Capacity building on threshing techniques and machinery' early warning systems
Hauling	Transportation of the cut crop to the farm	2.5%	Quantitative losses	Farmers	Rains, winds	Awareness raising/ capacity building on the best transportation techniques
Post harvest processes (on-farm)						
Drying	Drying outdoors using tarpaulins, and similar solutions		Spoilage, fungal damage, discoloration, smell, livestock foraging and breakage because of animal stamping	Farmers	Rains, winds	Plastic sheets and tarpaulins, rectangular cribs, moisture meters; early warning systems
On-farm storage	Storage in silos, bags or baskets	4.8%	Mold, insects, rodents	Farmers	Rains, winds, heat/ high temperatures	Metal and plastic silos, plastic and hermetic bags, Insecticides/ fumigation, storage structures; climate advisory
Primary processing (milling)	Milling using manual, partially mechanised or fully mechanised small-scale and industrial mills		Spillage, contamination with foreign materials	Millers	-	Trainings on milling technologies and machinery
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	1.0%	Spillage	Aggregators/ collectors and traders	Rains, winds	Plastic hermetic bags; non-hermetic polypropylene bags
Grading and packing	Sorting, pre-cleaning, re-packaging and packaging		Spillage, qualitative losses	Collectors and traders		Plastic hermetic bags; non-hermetic polypropylene bags
Storage	In bulk and/or in bags	2.7%	Spillage, qualitative losses	Storage companies, warehouses		Plastic hermetic bags, non-hermetic polypropylene bags. Insecticides/ fumigation
Wholesale	Packaging, storage, transportation to the sale points (markets, supermarkets)		Spillage, qualitative losses	Traders		
Secondary processing	Further processing into flour, products for snack and brewing industry, etc.		Spillage, qualitative losses	Secondary processors		

5.2 SHORT-LIST OF FOOD LOSS REDUCTION SOLUTIONS (FL-RS) BASED ON RESULTS OF CLIMATE ANALYSIS

This sub-chapter provides an overview of the most suitable physical and non-physical food loss reduction solutions for Ethiopia. RE-GAIN Programme aims to increase awareness of smallholder farmers in Ethiopia 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 Ethiopia 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 Ethiopia. The proposed FL-RS in those subchapters have been short-listed considering the specific context of Ethiopia 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 5-7.

Table 5-7 Indicative Awareness Raising and Capacity Building elements of RE-GAIN Programme in Ethiopia

	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.

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

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

Development of education materials will be implemented by AGRA national teams involved in the project, based on the most crucial topics identified for Ethiopia, 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 Ethiopia, 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 Ethiopia.

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 5-4* below.

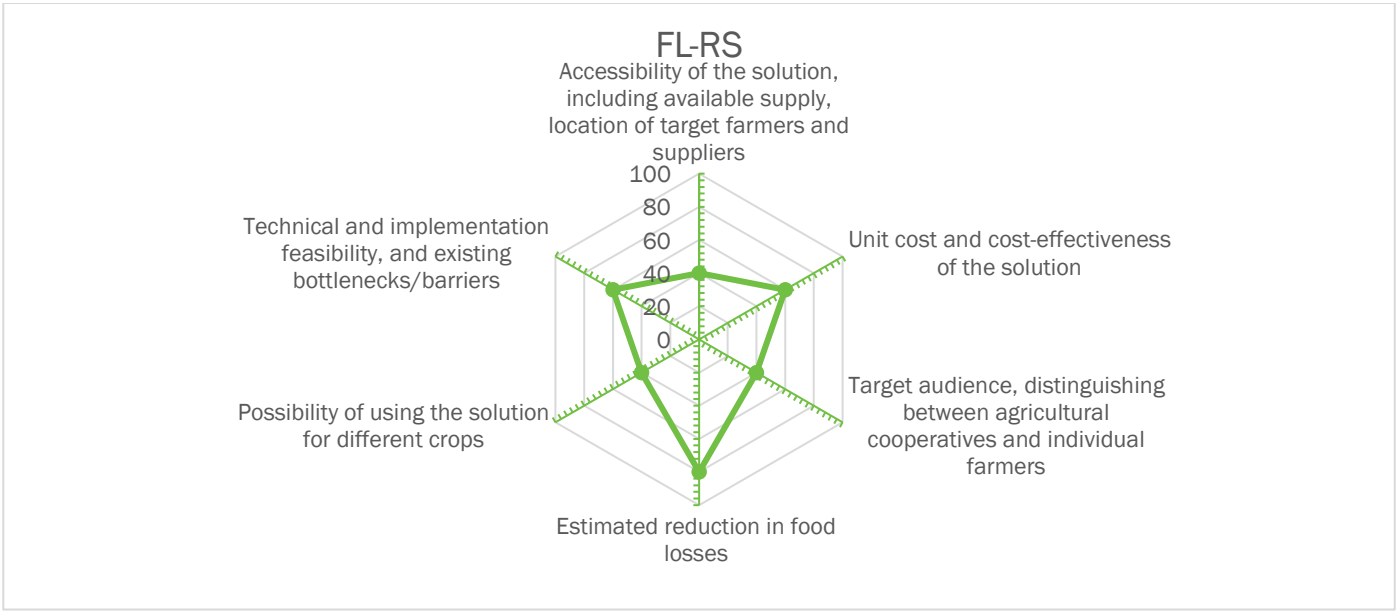


Figure 5-4 - FL-RS evaluation matrix

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

- Harvesting machinery (e.g., multi-crop harvesters)
- Mechanical multi-crop threshers and shellers
- Tarpaulins and plastic sheets
- Wooden and metal cribs
- Metal and plastic silos

- Hermetic and other plastic bags
- Moisture meters
- Storage structures (e.g., huts, baskets, grain sheds)
- Storage protectants and control agents (biological fumigants, insecticides and pesticides)
- Transport packaging (e.g., wooden crates and bags)

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

5.2.3.1 Harvesting machinery

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

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

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

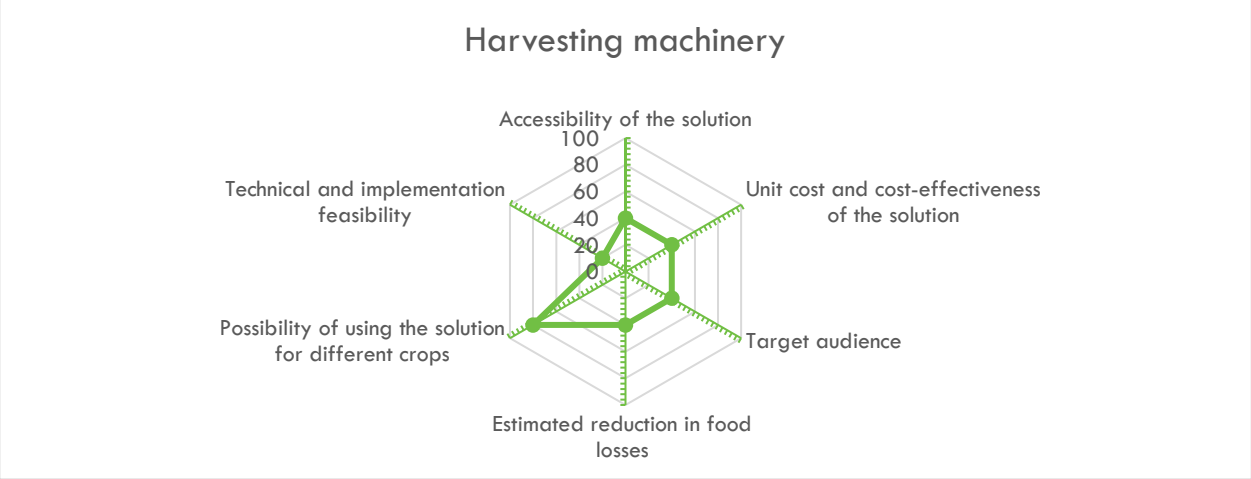


Figure 5-5 - FL-RS evaluation for harvesting machinery

5.2.3.2 Mechanical multi-crop threshers and shellers

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

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

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

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

The evaluation of mechanical multi-crop threshers and shellers is provided in Figure 5-6.

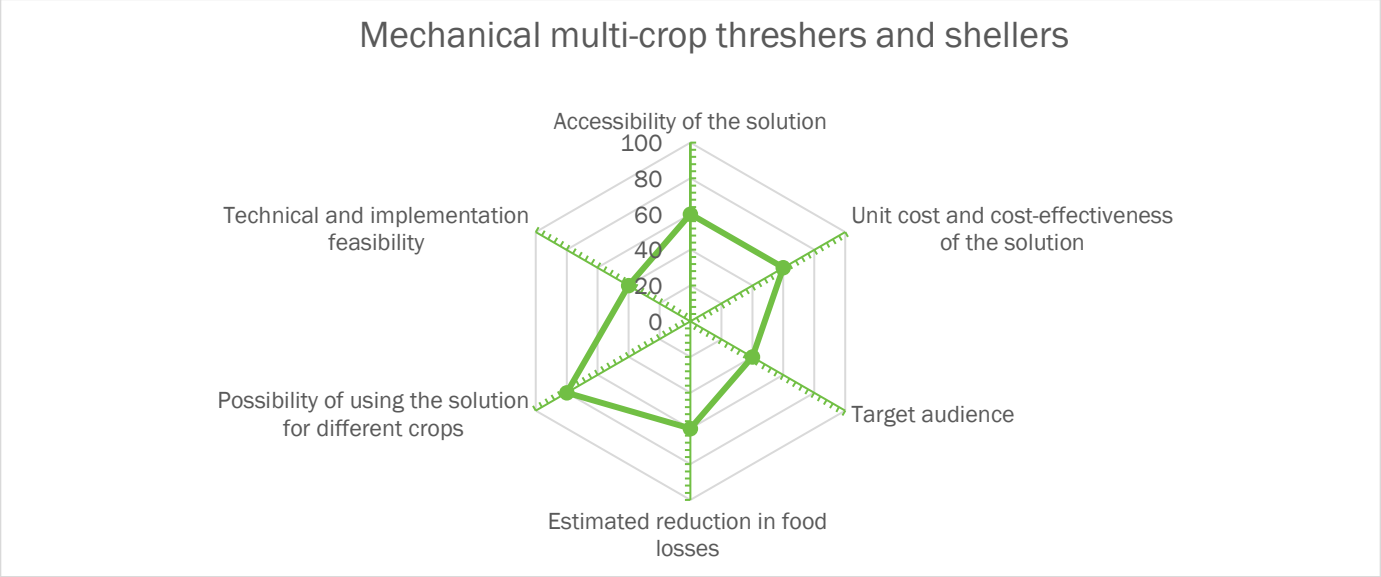


Figure 5-6 - FL-RS evaluation for mechanical multi-crop threshers and shellers

5.2.3.3 Tarpaulins and plastic sheets

Effectiveness and efficiency of using **tarpaulins and plastic sheets** for drying harvested crops such as maize and beans varies depending on the type of crop, local climate conditions, and pre-existing postharvest practices. For instance, in the case of grains and cereals such as rice, maize, and wheat, traditional drying methods often result in postharvest losses ranging from 10% to 30%, primarily due to spillage, spoilage, and contamination. However, the use of tarpaulins and plastic sheets can reduce these losses to between 5% and 10% by providing a clean, controlled drying environment (Hodges, 2011). Legumes and pulses, such as beans and lentils, which traditionally experience losses of 15% to 35%, can see a reduction to 5% to 15% when using improved drying methods with tarpaulins and plastic sheets (Grolleaud, 2002). This is primarily due to better protection from environmental factors and pests.

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

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

The evaluation of tarpaulins and plastic sheets is provided in Figure 5-7.

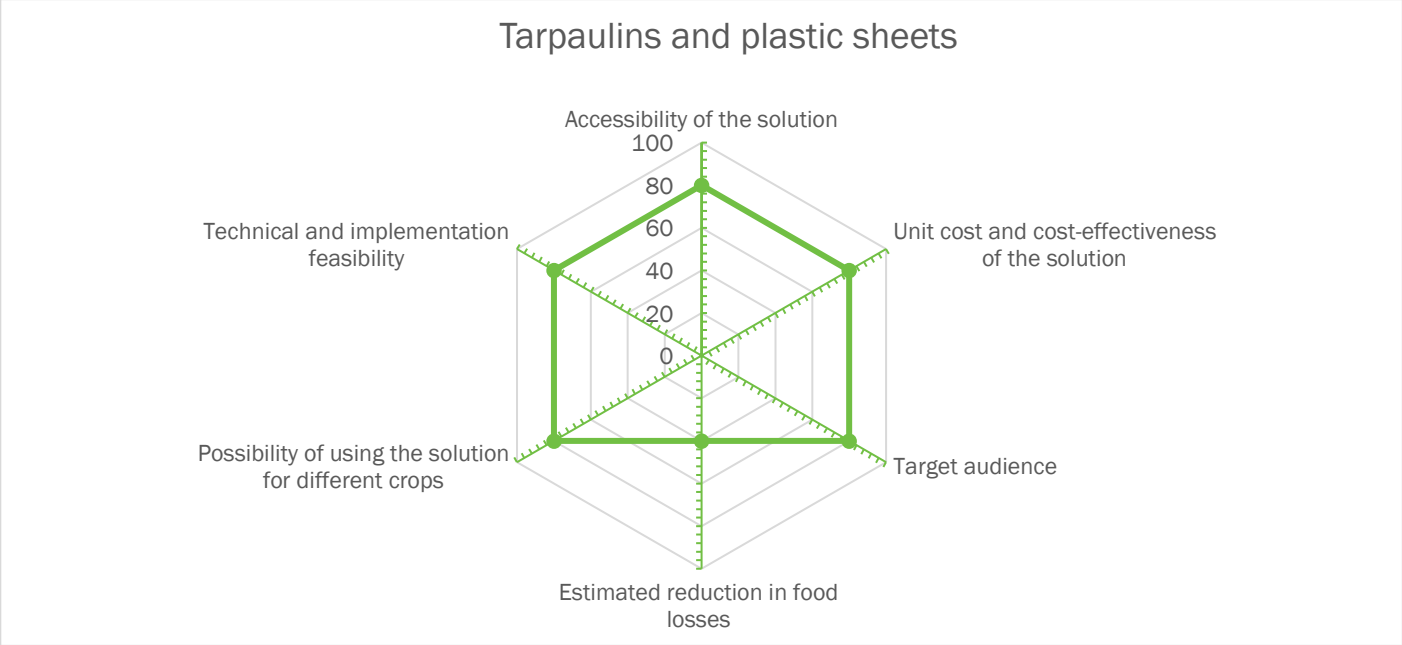


Figure 5-7 - FL-RS evaluation for tarpaulins and plastic sheets

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 5-8.

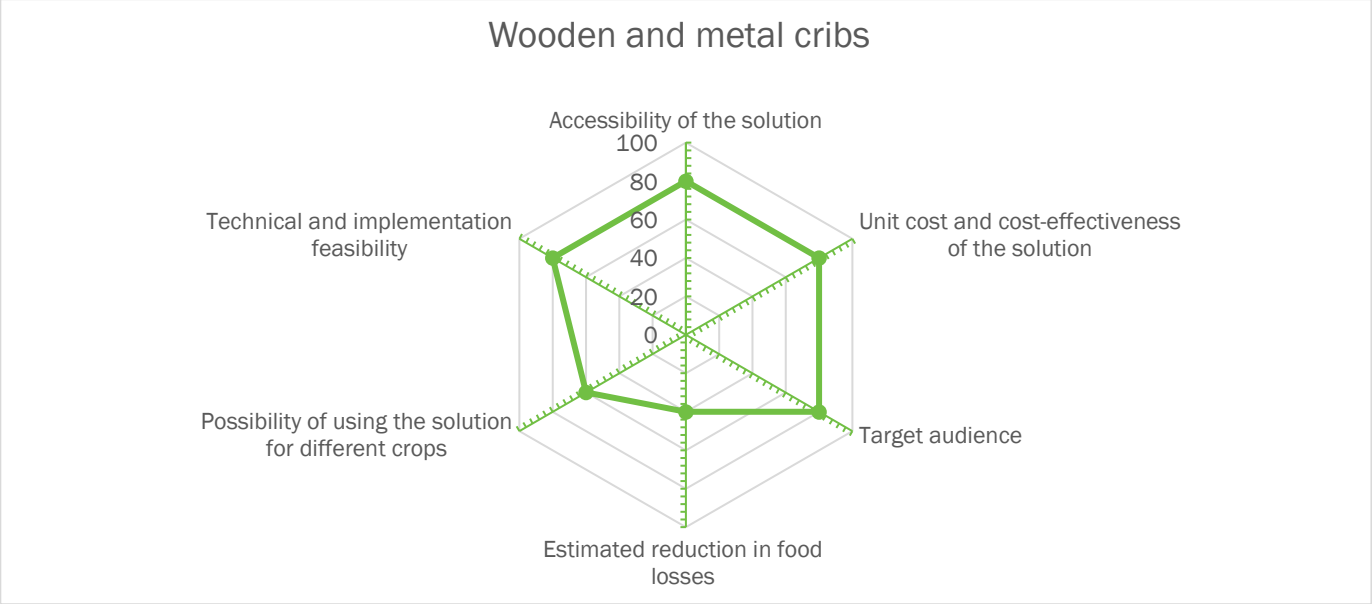


Figure 5-8 - FL-RS evaluation for wooden and metal cribs

5.2.3.5 Metal and plastic silos

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

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

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

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

hermetic nature of both metal and plastic silos eliminates the need for such chemicals, thereby promoting safer food practices and reducing environmental contamination.

The evaluation of metal and plastic silos is provided in Figure 5-9.

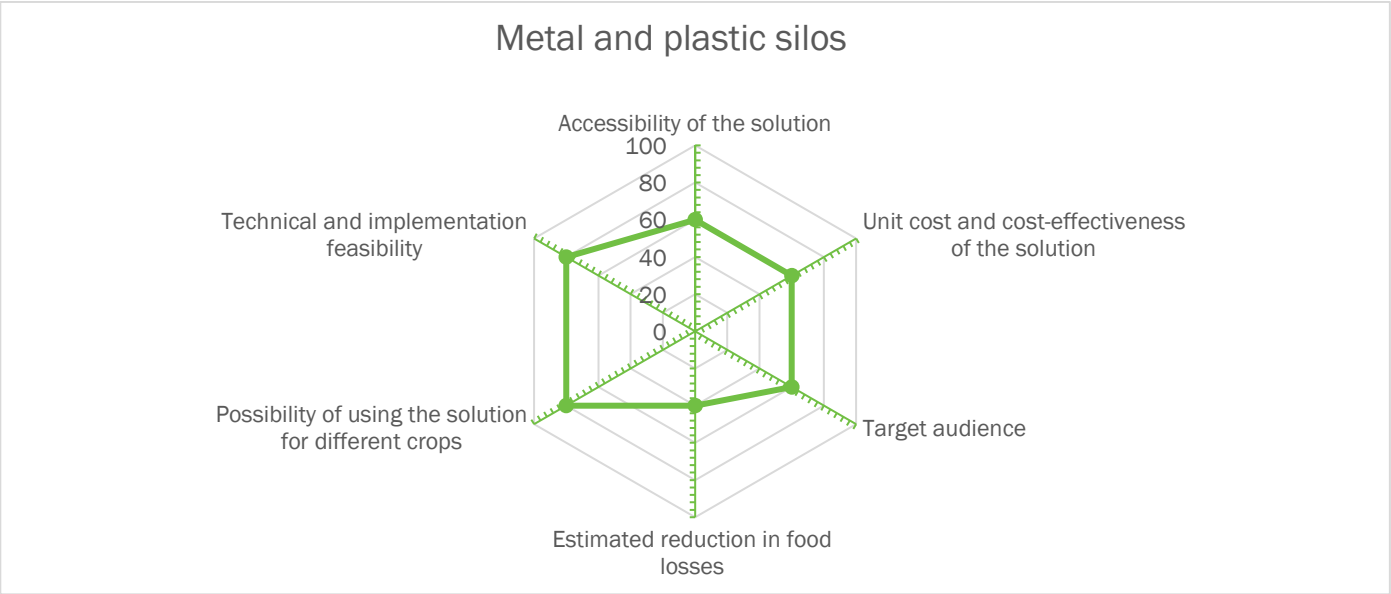


Figure 5-9 - FL-RS evaluation for metal and plastic silos

5.2.3.6 Hermetic bags

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

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

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

Despite the initial cost of hermetic bags being higher than traditional storage methods, the long-term economic and food security benefits make them a viable and beneficial investment (Baributsa, 2020). Scaling up the use of hermetic storage

solutions could significantly impact the fight against food insecurity in Sub-Saharan Africa, making it a key strategy in postharvest loss reduction efforts. As hermetic storage tools are made of plastics, within the scope of RE-GAIN programme we are looking primarily into the solutions made of recycled plastics. It is also important to consider the existing reuse and recycling approaches used in the target regions and encourage increased collection and recycling of the solutions previously being in use.

The evaluation of hermetic storage bags is provided in Figure 5-10.

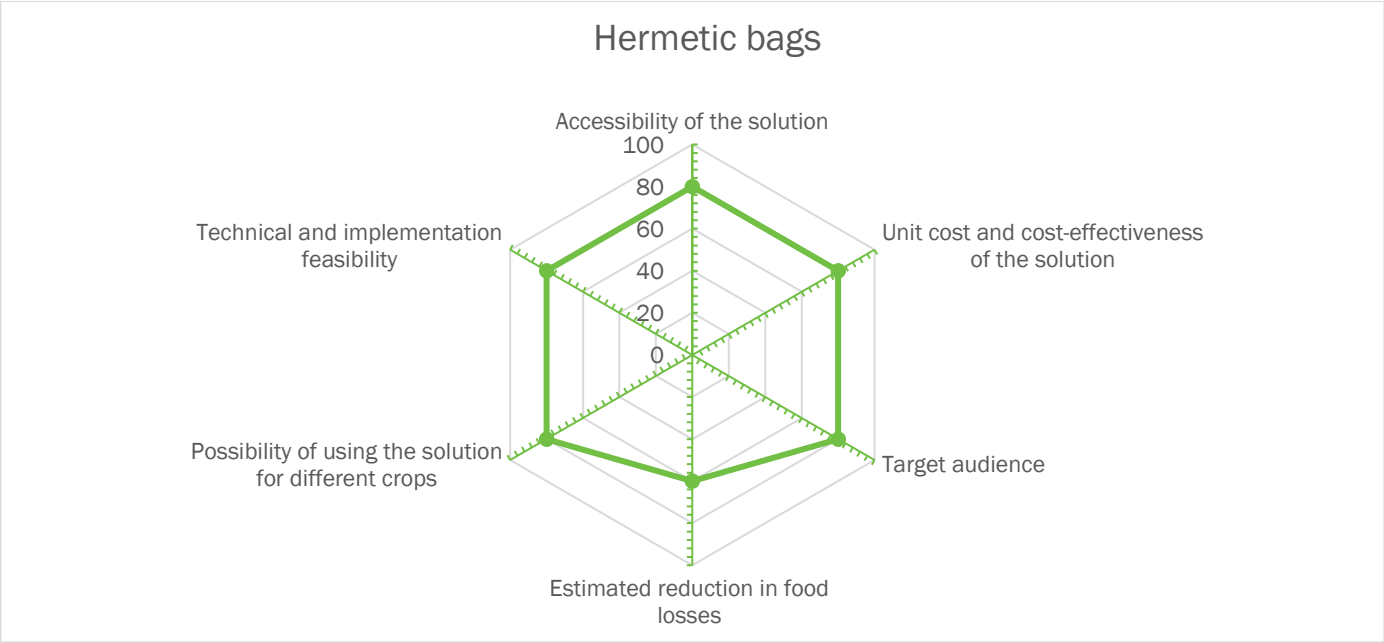


Figure 5-10 - FL-RS evaluation for hermetic bags

5.2.3.7 Moisture meters

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

The evaluation of moisture meters is provided in Figure 5-11.

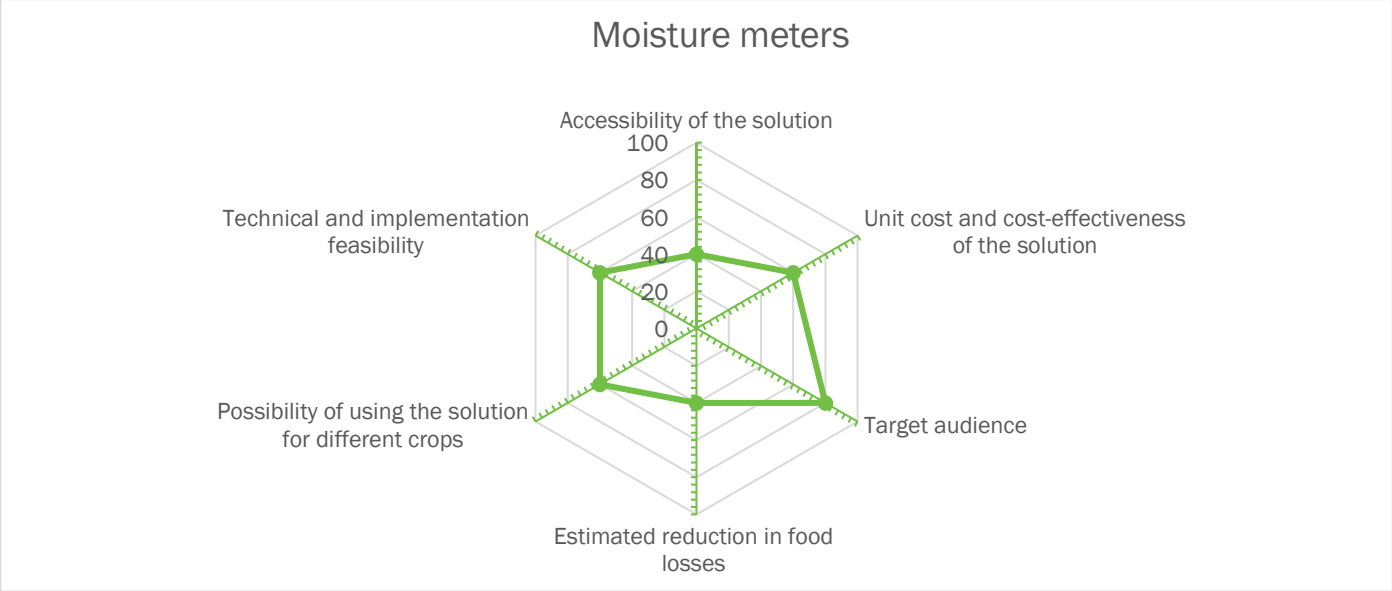


Figure 5-11 - FL-RS evaluation for moisture meters

5.2.3.8 Storage structures

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

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

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

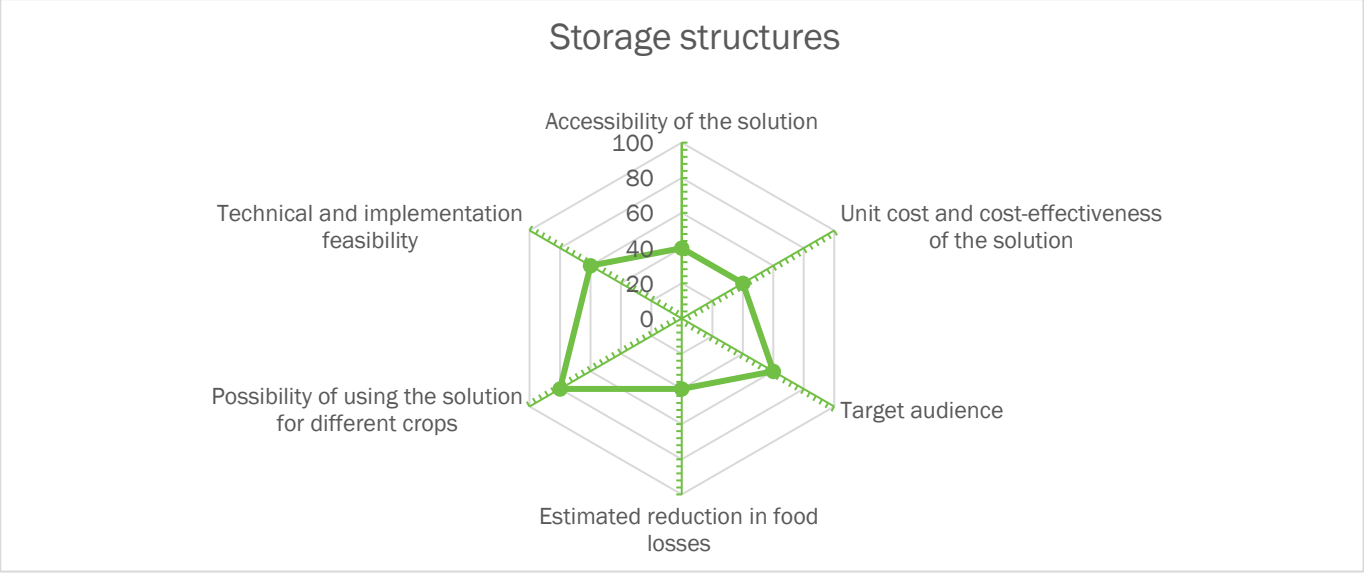


Figure 5-12 - FL-RS evaluation for storage structures

5.2.3.9 Storage protectants and control agents

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

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

The evaluation of storage protectants and control agents is provided in Figure 5-13.

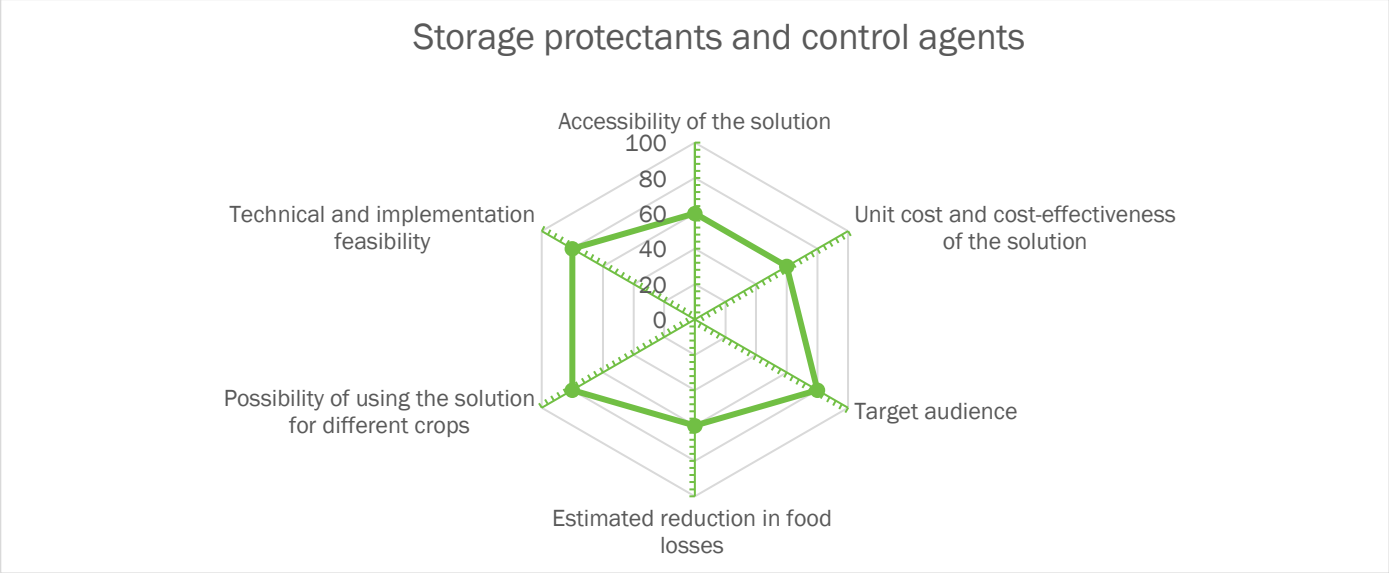


Figure 5-13 - FL-RS evaluation for storage protectants and control agents

5.2.3.10 Transport packaging

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

The evaluation of transport packaging is provided in Figure 5-14.

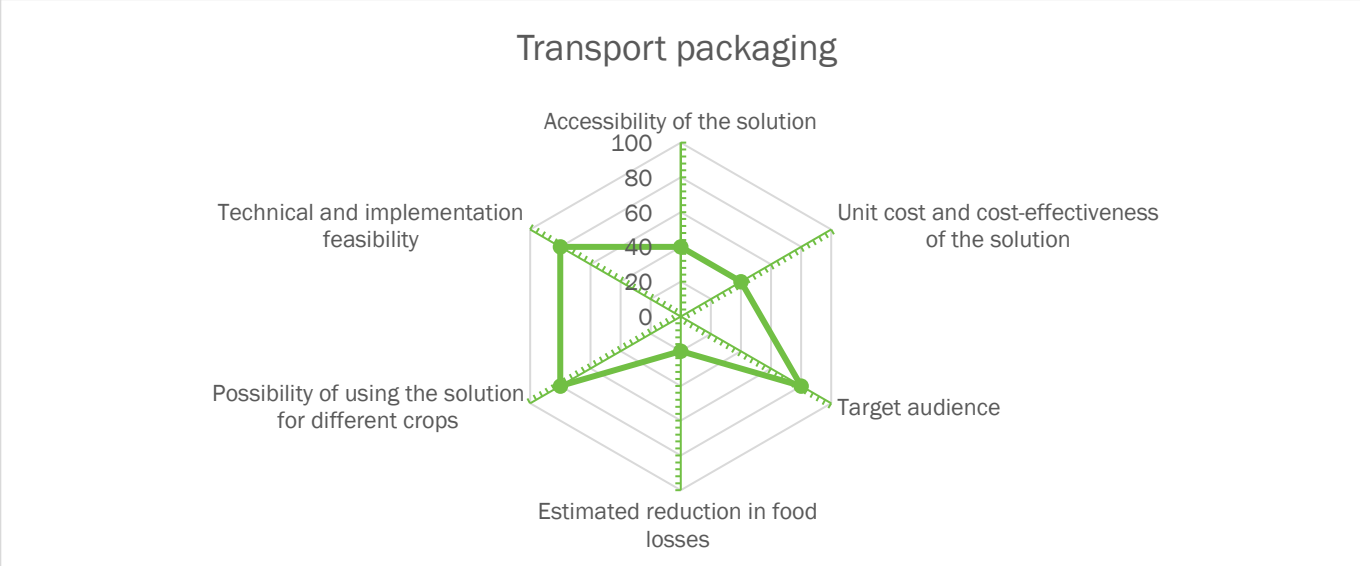


Figure 5-14 - FL-RS evaluation for transport packaging

Summary of the above-mentioned reduction in postharvest losses attributed to those 10 key physical FL-RS are presented in the *Table 5-8*.

Table 5-8 - Key physical FL-RS and their potential in reducing postharvest losses

Solutions	Estimated reduction in post-harvest losses, %
Harvesting machinery	**10-15%** *Sources:* (Hasan, 2020); (Mutungi, 2023); (Muhammad Yasin, 2019); (Aparna Kumari, 2023); (Mathanker, 2014)
Mechanical multi-crop threshers and shellers	**10-30%** *Sources:* (Amponsah, 2017); (FarmBiz Africa, 2020); (Getachew, 2022); (Soybean Innovation Lab, 2016)
Tarpaulins and plastic sheets	**10-20%** *Sources:* (Hodges, 2011); (Grolleaud, 2002); (Affognon, 2015); (Kitinoja L. S., 2011)
Wooden and metal cribs	**30-50%** *Sources:* (Julius, 2021); (FAO, 2011); (Tadele Tefera, 2011)
Metal and plastic silos	**10-50%** *Sources :* (Njoroge, 2019); (De Groote H. K., 2013)
Hermetic and other plastic bags	**20-30%** *Sources:* (Williams, 2017); (De Groote H. K., 2012); (Koskei, 2020)
Moisture meters	**Up to 25%** *Sources:* (Hossain, 2016); (Koskei, 2020)
Storage structures	**Up to 15%** *Sources:* (Befikadu, 2014); (FAO, 2014); (Ansah, 2018)
Storage protectants and control agents	**30-40%** *Sources:* (Tefera, 2011); (Abass, 2014)
Transport packaging	**10-15%** *Sources:* (Affognon, 2015); (Adejumo, 2007)

5.3 DEFINITION OF FEASIBILITY AND PRIORITISATION CRITERIA FOR FL-RS

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

- Solutions that respond to the identified climate risks in the teff and wheat value chains

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

5.3.1 Solutions that respond to the identified climate risks in the teff and wheat value chains

In terms of climate risks, both teff and wheat in Ethiopia 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 3-13). The erratic nature of rainfall is adversely affecting the productivity of teff and wheat production in Ethiopia. It sometimes results in intense rainy days when teff and wheat are ready for harvesting. Such conditions negatively impact the overall yield during harvesting, the quality of the crops and the noted increase in pests. Unexpected heavy rains during post-harvest 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. 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 teff and wheat value chains in Ethiopia is presented in Table 5-9 and Table 5-10 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 5-9 - Evaluation of the potential solutions in addressing key climate hazards in Ethiopia for the teff value chain

Solutions	Climate hazards			Average rate
	Increased average temperatures, hot days over 35 °C, and extreme heat and heatwaves	Heavy rains (days with rainfall over 20 mm, large 1-day rains and large 5-day rains)	River and/or urban floods	
Harvesting machinery	4	4	4	4.00
Mechanical multi-crop threshers and shellers	5	4	4	4.33
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	5	4	4.33
Moisture meters	3	4	3	3.33
Storage structures	4	4	4	4.00
Storage protectants /control agents	3	3	3	3.00
Transport packaging	2	2	2	2.00

Table 5-10 - Evaluation of the potential solutions in addressing key climate hazards in Ethiopia for wheat value chain

Solutions	Climate hazards			Average rate
	Increased average temperatures, hot days over 35 °C, and extreme heat and heatwaves	Heavy rains (days with rainfall over 20 mm, large 1-day rains and large 5-day rains)	River and/or urban floods	
Harvesting machinery	4	4	4	4.00
Mechanical multi-crop threshers and shellers	4	4	4	4.00
Tarpaulins and plastic sheets	4	2	2	2.67

Wooden and metal cribs	3	3	3	3.00
Metal and plastic silos	4	4	4	4.00
Hermetic bags	4	5	4	4.33
Moisture meters	3	4	3	3.33
Storage structures	4	4	4	4.00
Storage protectants /control agents	4	3	3	3.33
Transport packaging	3	2	2	2.33

Based on the Tables above, the FL-RS with the highest average scoring for Ethiopia are the following, presented in the order of importance:

- Hermetic bags (4.33 points for both teff and wheat)
- Mechanical multi-crop threshers and shellers (4.33 points for teff and 4.00 points for wheat)
- Metal and plastic silos (4.33 points for teff and 4.00 points for wheat)
- Harvesting machinery (4.00 points for both teff and wheat)
- Storage structures (4.00 points for both teff and wheat)
- Moisture meters (3.33 points for both teff and wheat)
- Storage protectants and control agents (3.33 points for wheat and 3.00 points for teff)
- Tarpaulins and plastic sheets (2.67 points for both wheat and teff)

Baseline research findings described in subchapter 5.1 have identified harvesting, stacking/piling, threshing, storage and retail for teff, and harvesting, threshing, transportation and storage for wheat as critical loss factors. Considering the key climate hazards in the context of Ethiopia, those FL-RS also need to address the issue of rising temperatures. Therefore, it is important to consider storage solutions that are resilient to overheating and ensure protection from moisture caused by rainfall. It becomes even more important since pest and rodent infestations represent an additional significant factor contributing to post-harvest food losses in the teff and wheat value chains, and those are primarily exacerbated by heat and inadequate storage facilities and techniques. Therefore, it is imperative to ensure the provision of durable, well-ventilated, and dry storage facilities. Effective storage solutions must encompass both on-farm and communal storage options to 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 post-harvest loss reduction solutions, during both rounds of stakeholder engagements in Ethiopia.

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

Table 5-11 Estimation of the costs of top 10 FL-RS in Ethiopia

Solutions	Estimated cost of the solution in US dollars	Scoring
Harvesting machinery	Average 124 684	1
Mechanical multi-crop threshers and shellers	Est. 7 100 – 11 500	2
Storage structures	Est. 130 - 500	3
Moisture meters	Est. 45 - 160	3
Metal and plastic silos	Est. 100 - 200	3
Wooden and metal cribs	Est. 20 - 80	3

Tarpaulins and plastic sheets	Est. 21-26	4
Transport packaging	Est. 2 - 20	4
Storage protectants and control agents	Est. 2 - 16	4
Hermetic bags	Est. 1.6 – 1,9	5

Sources: (Ethio Engineering Group, 2024); (AMIO, 2024); (GrainPro, 2024)

While affordability and availability of the solutions will be addressed by 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 Ethiopia, 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 Ethiopia.

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 post-harvest losses in Ethiopia 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 teff and wheat coupled with insufficient knowledge regarding the optimal use of most food loss reduction solutions (FL-RS) available on the market.

In terms of key stages of post-harvest losses identified for Ethiopia during the baseline assessments (Chapters 3 and 4), and the first round of stakeholder engagement on national and local levels, major losses in both teff and wheat value chains are observed on the harvesting, and post-harvest handling and storage stages. For teff, retail is another significant food loss stage.

During the first round of stakeholder consultations in Ethiopia conducted in June 2024, each group of participants of local and national workshops shortlisted the top three solutions, that would be relevant for both teff and wheat 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 5-12.

Table 5-12 - Top solutions for teff and wheat production, resilience against climate risks, and impact potential for smallholder farmers in Ethiopia

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

As we can see from the table, the most important solutions include multi-crop threshers and shellers, harvesting machinery, storage structures and hermetic bags. For the final evaluation provided in the Table 5-13, 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 Ethiopia specified in the previous chapters, the physical FL-RS for teff and wheat in Ethiopia with the highest potential to reduce post-harvest food losses are highlighted in Table 5-13 below:

Table 5-13 - Final evaluation of the shortlisted physical FL-RS in Ethiopia

Solutions	Climate risks		Costs of the solutions	Best solutions in the local context	Final score
	Teff	Wheat			
Harvesting machinery	4.00	4.00	1	3	12.00
Mechanical multi-crop threshers and shellers	4.33	4.00	2	3	13.33
Tarpaulins and plastic sheets	2.67	2.67	4	2	11.34
Wooden and metal cribs	2.00	3.00	3	0	8.00
Metal and plastic silos	4.33	4.00	3	3	14.33
Hermetic bags	4.33	4.33	5	3	16.66
Moisture meters	3.33	3.33	3	1	10.66
Storage structures	4.00	4.00	3	3	14.00
Storage protectants and control agents	3.00	3.33	4	1	11.33
Transport packaging	2.00	2.33	4	0	8.33

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

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

Based on the results of stakeholder engagements in Ethiopia, 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 the Table 5-14.

Table 5-14 - Results of the shortlisted FL-RS evaluation in Ethiopia

Solution	Strategic advantages of the solution	Key disadvantages of the solution	key barriers to solution implementation	Additional points based on discussions with stakeholders
Harvesting machinery	Time and labour-saving, are especially beneficial for large-scale farming operations, significantly boosting efficiency and productivity.	Costly to purchase and maintain. Furthermore, this kind of machinery is suitable primarily for big farms or cooperatives	High costs of procurement and maintenance, and the need for large-scale operations to justify the investment	Stakeholders are aware about 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 post-harvest mechanisation
Mechanical Multi-Crop Threshers and Shellers	Time and labour – saving, simplifies the post-harvest process. Easy to use, enhances efficiency in farming operations	High costs, both for procurement and maintenance, can be prohibitive	High initial cost of purchase and maintenance	
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 Ethiopia frequently dry their crops on open ground or mats, a practice that can lead to significant wastage. To mitigate these losses, 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.	The high expense for smallholder farmers, the necessity for technical skills, and ongoing monitoring requirements	Consulted stakeholders highlighted the need for skills to construct those silos and the requirement to monitor temperature and moisture levels

Solution	Strategic advantages of the solution	Key disadvantages of the solution	key barriers to solution implementation	Additional points based on discussions with stakeholders
Storage Structures	Help maintain the quality of produce and are adaptable to various weather conditions.	Prone to theft and other security issues and can be costly to sustain	High cost of construction and maintenance and the scarcity of materials required for building these structures	Storage structures are important for different scales of farming operations. Effective post-harvest food loss reduction should include both on-fam and community storage solutions
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	Provides accurate measurements, ensures required grain moisture levels. Helps to maintain the quality of the grains, and reduce post-harvest losses	Personnel needs to be trained to operate them accurately. The cost of these devices makes them unaffordable for many smallholder farmers	Lack of funds. Need for proper training of farmers to use it effectively	Suitable and effective solution for the community level. Farmers usually need to check the level of moisture before storage, and during storage
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 the specific needs of the farmers in Ethiopia. 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 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 5-15.

Table 5-15 Prioritized physical FL-RS for Ethiopia

Solutions	Level of priority
Harvesting machinery	medium
Mechanical multi-crop threshers and shellers	high
Tarpaulins and plastic sheets	medium
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

Regarding the feasibility of implementing harvesting machinery as a prioritized solution in Ethiopia, considering the substantial costs and technical requirements associated with the utilization and maintenance of such equipment, we suggest engaging through the development of partnerships with existing agricultural service providers in these countries as the most effective strategy. AGRA team in Ethiopia will facilitate the creation of demand and awareness about the advantages of harvesting machinery, particularly in terms of mitigating food losses during harvest induced by climate hazards, through consortia with key relevant partners. This strategy will ensure both direct and indirect engagement with the target farmers.

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 Ethiopia to be deployed as a basket of options, bespoke combinations such as harvesting machinery, 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 Ethiopia, as well as their potential to reduce post-harvest losses in teff and wheat value chains and existing barriers, Table 5-16 provides a brief overview of the proposed solutions' delivery mechanism for Ethiopia.

Table 5-16 - Proposed delivery mechanism for shortlisted physical FL-RS in Ethiopia

Solution	Estimated reduction in PHL, % (Table 5-1)	Barriers for solution implementation	Proposed delivery mechanisms
Harvesting machinery	10-15%	• High costs of procurement and maintenance • Need for large-scale operations to justify the investment • Need for technical skills and knowledge about operating those harvesters	• Capacity building (training of trainers) on managing and maintaining the machinery
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 subsidy scheme • Capacity building (training of trainers) on the 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 subsidy scheme • Trainings and capacity building on the appropriate use of tarpaulins and plastic sheets
Metal and plastic silos	10-50%	• High cost • Need for monitoring and maintenance	• Improved access to solutions through 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 subsidy scheme • Capacity building (training of trainers) on the best practices in using storage structures
Hermetic bags	20-30%	• Affordability / cost of the bags • Limited access to finance	• Improved access to solutions through subsidy scheme • Training and capacity building on the appropriate use of hermetic bags
Moisture meters	Up to 25%	• Lack of funds • Need for proper training of farmers to use it effectively	• Improved access to solutions through subsidy scheme • Training and capacity building on the appropriate use of moisture meters
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 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 Ethiopia, 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 5-17:

Table 5-17 Proposed Activities Set and Outputs of the RE-GAIN Programme, aligned with the identified risks, needs and barriers in access to FL-RS

Identified risks, needs and barriers	Activity sets	Outputs
Technical and Operational Challenges • Technical challenges in use of technologies and equipment • Susceptibility of crops to weather conditions, pests, and contamination • Limited access to markets for smallholder products • Limited awareness of impact of climate change on harvest and post-harvest crop management • Limited awareness of the use of climate information for decision making	Activity Set 1 • Gender-responsive awareness campaign on the impacts of CC on post-harvest food losses and the availability of FL-RS. • Demonstration, training and tech. transfer for the use of weather/ climate information, FL-RS and related practices • Capacity development of extension services and agro-dealers	Output 1.1. Smallholder farmers supported to adopt FL-RS
Skills and Knowledge Requirements • Limited awareness of impact of climate change on harvest and post-harvest crop management • Limited awareness of the use of climate information for decision making • Need for proper training, knowledge, and technical skills for effective use and maintenance of equipment and post-harvest technologies • Limited awareness and knowledge about proper usage and management of FL-RS Health, Safety, and Environmental Risks • High pollution risks and environmental impacts of certain harvesting technologies • Health and safety concerns associated with the use of chemical products as storage protectants	Activity Set 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	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
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 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	Activity Set 5	Output 3.1. Enhanced capacity of national

Identified risks, needs and barriers	Activity sets	Outputs
• **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**	• 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	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[2] 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

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

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[3] and will be comprised of country-office staff. The CIUs will be responsible for managing day-to-day operations in each country, reporting directly to the PIU, as well as providing regular reports to the relevant Project Steering Committee (see below).

Programme Steering Committee

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

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

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

Table 5-18: Country PSC Representatives

Country	PSC Representatives
Ethiopia	• Ministry of Agriculture (State Minister, Agriculture & Horticulture Sector) • Ethiopian Agricultural Transformation Institute. • Ethiopian Agricultural Authority (regulatory body) • Ministry of Planning and Development (NDA) • Green Agro-Solutions

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

	• Dashen Bank

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.

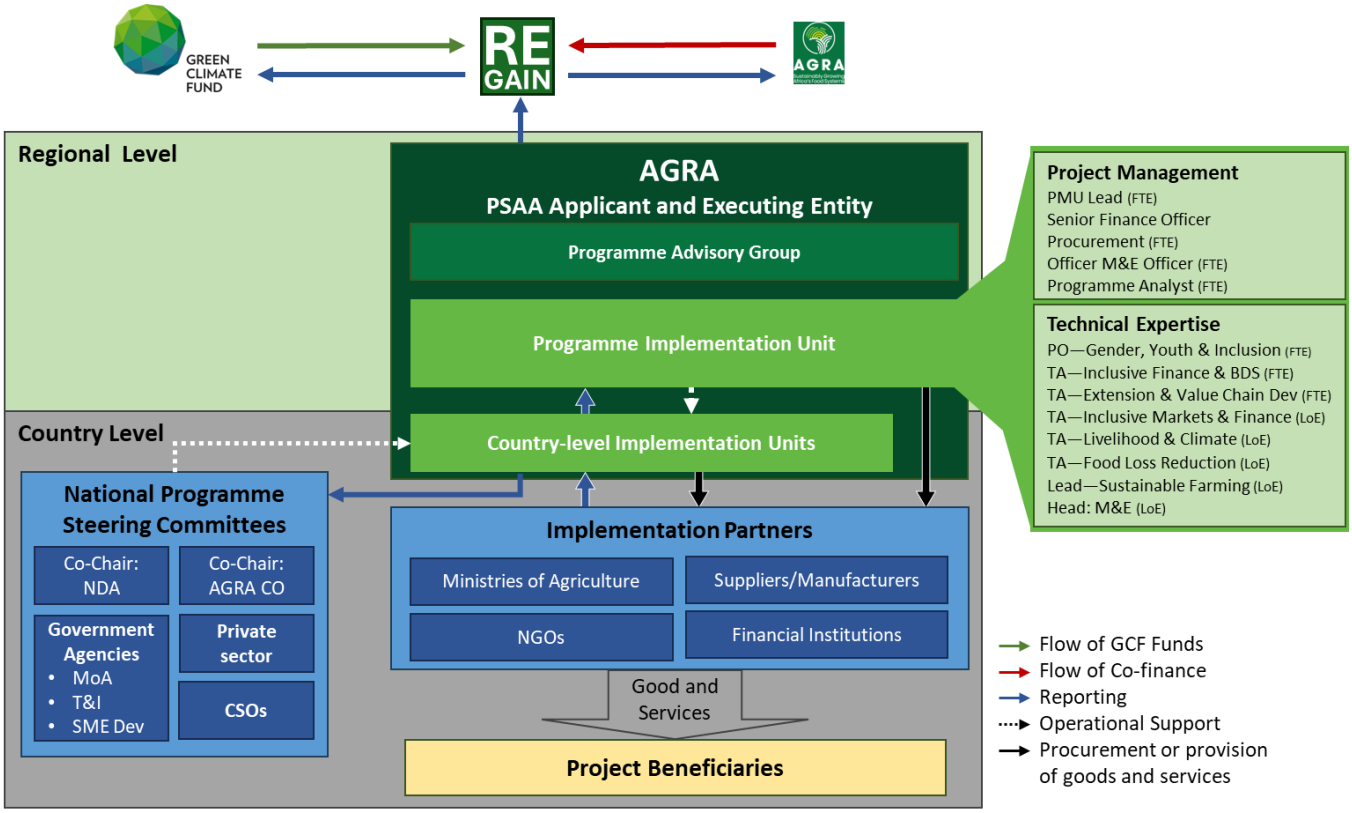


Figure 5-15 Implementation Arrangements for the RE-GAIN Programme

5.8 PROGRAMME AREA

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

5.8.1 Eligibility criteria for programme area

- Selection of geographical location in the target countries for the RE-GAIN project. Below is the selection criteria that will be considered:

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

6 Market Dynamics Study

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

6.1 CURRENT DEMAND FOR THE PRIORITISED FL-RS

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

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

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

6.1.1 Demand for specific FL-RS

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

Mechanical multi-crop threshers and shellers are highly sought after in Ethiopia. The demand for is driven by several interrelated factors that underscore the critical need for these technologies within the agricultural sector. They are particularly beneficial for farmers growing diverse crops, as they significantly boost productivity and lower labour expenses. With increasing agricultural output, there is a corresponding need to efficiently process larger volumes of harvested crops, and

mechanized threshing and shelling improve the overall quality of grains by minimizing breakage and impurities, thereby enhancing their market value and competitiveness. As the agricultural sector modernizes and seeks to enhance productivity, there is a clear and pressing demand for mechanized solutions that can streamline these processes. Despite this clear demand, several challenges hinder the widespread adoption and availability of threshers and shellers in Ethiopia. Financial constraints are a major barrier, as the cost of these machines is often prohibitive for smallholder farmers, who constitute the majority of the farming population. Imported threshers are often too expensive for smallholder farmers, and local production is not yet at a scale that meets demand. Moreover, maintenance and repair services are sparse, complicating the long-term use of these machines. And even when farmers are aware of the benefits, the lack of access to affordable credit and financing options limits their ability to purchase these technologies. Another significant barrier is the lack of adequate training and extension services to educate farmers on the operation and maintenance of threshers and shellers. Many farmers may be unfamiliar with mechanized threshing and shelling processes, leading to suboptimal use of the equipment and potential operational challenges.

The demand for **tarpaulins and plastic sheets** in Ethiopia's agricultural sector is driven by the necessity to address significant post-harvest challenges, particularly those related to drying, protecting, and storing crops. Tarpaulins and plastic sheets offer a practical and cost-effective solution by providing a clean and controlled surface for drying crops, thereby protecting them from such hazards. This demand is particularly strong during the harvest seasons when the need for efficient drying mechanisms is at its peak. Their adoption is more widespread compared to other technologies, as they are relatively affordable and accessible. However, issues with quality and durability persist, with many available products not meeting the necessary standards to effectively prevent moisture and pest damage. Distribution challenges, especially in remote areas, also limit their availability.

Hermetic bags have seen a surge in demand in Ethiopia, driven by the critical need to address post-harvest losses and improve the storage of grains and other crops. These bags are particularly beneficial for smallholder farmers who need affordable and effective storage solutions. However, several challenges hinder the widespread adoption of hermetic bags in Ethiopia. One of the primary barriers is the cost. Although hermetic bags are a cost-effective solution in the long run, their initial purchase price can be relatively high for smallholder farmers, who make up the majority of the farming population. Many of these farmers operate on tight budgets and may not have the financial capacity to invest in hermetic bags without external support. Another significant barrier is the lack of awareness and understanding of the benefits and proper use of hermetic bags. Many farmers continue to rely on traditional storage methods simply because they are unaware of better alternatives or do not fully understand how hermetic bags work. Distribution challenges also play a crucial role in limiting access to hermetic bags. The supply chains for these bags are often underdeveloped, particularly in remote and rural areas where they are needed most. Additionally, there is a lack of local manufacturing capacity, which means that many hermetic bags must be imported, further increasing costs and limiting availability.

The demand for **metal and plastic silos** in Ethiopia is moderate. Despite the clear benefits and rising demand, the use of silos is still limited, with high initial costs being a significant barrier. While some government and non-governmental programs promote silo adoption through subsidies and awareness campaigns, the overall penetration remains low. Farmers also need training on the proper use and maintenance of these silos to maximize their benefits. Furthermore, the local manufacturing capacity for producing high-quality silos is limited, resulting in reliance on imports, which can increase costs and complicate supply chains.

Moisture meters are getting more popular as Ethiopian farmers recognize their significant potential in improving post-harvest management and ensuring the quality and marketability of stored grains. However, most moisture meters are imported,

making them expensive and limiting their distribution. Besides that, many farmers are unfamiliar with these devices and may not fully understand how to use them effectively, which can lead to scepticism about the value of investing in moisture meters. Extension services and educational programs are often limited, leaving a gap in the necessary training and support for farmers.

There is a high demand for **improved storage structures** to reduce post-harvest losses and enable farmers to store crops longer to achieve better prices. The establishment of these structures is growing, supported by various development programs and cooperatives. However, challenges such as securing funding, land, and proper management structures limit their effectiveness. Organizational capacity and governance issues also need to be addressed to ensure these communal facilities are used efficiently and equitably. Enhanced access to affordable storage solutions and management training would significantly benefit smallholder farmers in Ethiopia.

The economic benefits associated with the use of **crop protectants and control agents** in Ethiopia are a major factor driving their demand. Those solutions, including chemical and biological agents, are crucial for managing pests and diseases during storage. The use of these protectants is increasing, driven by the need to reduce post-harvest losses and improve the quality of stored produce. However, challenges such as the high cost of quality protectants, limited availability, and inadequate regulatory frameworks to prevent the sale of substandard products impede their widespread use. Additionally, many farmers lack the knowledge to use these protectants effectively and safely, highlighting the need for better extension services and training programs.

6.2 MARKET OF SUPPLIERS AND MANUFACTURERS OF FL-RS

The current market situation for food loss reduction solutions in Ethiopia involves a diverse range of suppliers, manufacturers, and importers, each playing a critical role in addressing post-harvest challenges. The landscape is characterized by a mix of local production and significant reliance on imported technologies, with varying degrees of accessibility and affordability impacting their widespread adoption.

Threshers and Shellers: Local manufacturing of threshers and shellers is limited, with only a few Ethiopian companies producing these machines at a scale that meets national demand. Companies such as Ethio-Engineering Group (EEG)/ Adama Agricultural Machinery Industry (AAMI), Mesfin Industrial Engineering PLC, Amio Engineering and Ethio-Nippon Technical Company (ENTC) produce and supply agricultural machinery, including threshers and shellers. However, the majority of these machines are imported from countries like India and China, with importers playing a crucial role in bridging the gap between supply and demand. Importers and distributors such as Hagbes Plc and Gedeb Engineering Plc are significant players in this market.

Tarpaulins and Plastic Sheets: The market for tarpaulins and plastic sheets is more developed, with several local manufacturers and suppliers. Companies like Ethiopia Plastics Industry, JMBS Import, Kebron, Adama, and Canal Plastics produce a range of plastic products, including tarpaulins and sheets used in agriculture. Importers also bring in tarpaulins from countries like China and India, ensuring a steady supply to meet the needs of Ethiopian farmers. The distribution network for these products is relatively extensive, with various retailers and wholesalers operating in urban and rural areas.

Hermetic Bags: The market for hermetic bags in Ethiopia is growing, with both local production and imports contributing to the supply. Local companies like Shayashone PLC produce hermetic bags tailored for grain storage. International

organizations and development programs, such as the Purdue Improved Crop Storage (PICS) project, also facilitate the distribution of hermetic bags. Importers play a significant role, bringing in products from manufacturers in countries like Kenya and India. Retailers and agricultural cooperatives are key distribution points for these bags.

Metal and Plastic Silos: The production of metal and plastic silos in Ethiopia is relatively limited, with only a few local manufacturers such as Ethio-Engineering Group (EEG)/ Adama Agricultural Machinery Industry and AMIO Engineering are involved in this sector. Most of the silos are imported, with suppliers sourcing them from international manufacturers in countries like China and India.

Moisture Meters: The market for moisture meters is predominantly import-driven, with few local manufacturers producing these specialized devices. Companies like MFI Ethiopia and Bako Agricultural Research Center are involved in supplying moisture meters, but the majority are imported. Key importers and distributors include Green Agro Solutions and YONAD Business Promotion and Consultancy, which provide these meters to agricultural cooperatives, retailers, and directly to farmers.

Communal Storage Structures: The development of communal storage structures often involves a combination of local construction companies and international aid organizations. Local construction firms, such as Orchid Business Group and TACON, are frequently contracted to build these structures. International organizations like the World Food Programme (WFP) and the Food and Agriculture Organization (FAO) also contribute by funding and facilitating the construction of these storage facilities. Local NGOs and cooperatives play a crucial role in managing these structures and ensuring they meet the needs of the farming communities.

Crop Protectants and Control Agents: The market for crop protectants and control agents includes both locally produced and imported products. Ethiopian companies like Adami Tulu Pesticides Processing Plc and Africa Agro Chemicals Plc produce a range of pesticides and control agents. However, a significant portion of these products is imported from countries like China, India, and the United States.

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 Ethiopia

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

The results of the research together with the consultations with stakeholders in Ethiopia have identified several financial initiatives designed to improve access to physical FL-RS. Those initiatives are primarily led by the government of Ethiopia, as well as international donors and international and national NGOs.

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

The Development Bank of Ethiopia (DBE) is a government programme that supports large-scale agricultural projects, including those focused on postharvest handling and storage. Through its various loan products, the DBE aims to enhance the capacity of farmers and agribusinesses to manage their produce effectively.

Government – led initiatives implemented in Ethiopia in the recent years include:

1. **Rural Financial Intermediation Program (RUFIP):** The Rural Financial Intermediation Program (RUFIP) is a major government initiative aimed at improving access to financial services in rural areas. RUFIP provides financial support to Microfinance Institutions (MFIs) and rural cooperatives, enabling them to offer microcredit to farmers. The program focuses on expanding the reach of financial services in rural areas, enhancing the capacity of MFIs and cooperatives to provide loans, and facilitating the development of appropriate financial products for farmers.
2. **Regional Microfinance Support Programs:** Various regional governments in Ethiopia have implemented their own microfinance support programs to cater to the specific needs of farmers in their areas. These programs often work in collaboration with regional MFIs and cooperatives to provide tailored microcredit solutions. Examples include Oromia Microfinance Institution (OMFI) in the Oromia region, Amhara Credit and Savings Institution (ACSI) in the Amhara region, and Southern Region Microfinance Institution (SMFI) in the Southern Nations, Nationalities, and Peoples' Region (SNNPR).

International organizations and NGOs also contribute significantly to this effort. USAID's Feed the Future Program, for example, provides financial support and loans aimed at improving agricultural productivity and postharvest management. These initiatives are crucial for building a resilient agricultural sector in Ethiopia.

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

1. **USAID: Feed the Future:** This flagship programme of USAID works to reduce hunger and poverty by increasing agricultural productivity. It includes components that provide microcredit and financial services to smallholder farmers to help them invest in inputs, technologies, and practices that boost productivity.
2. **FAO (Food and Agriculture Organization): Microfinance for Agriculture:** FAO collaborates with local MFIs and cooperatives to develop and promote microcredit schemes that help farmers invest in agricultural inputs, technologies, and practices that enhance productivity and sustainability.
3. **UNDP (United Nations Development Programme) Inclusive Finance Program:** This programme aims to improve access to financial services for underserved populations, including smallholder farmers. It supports the development of microcredit products and strengthens the capacity of financial institutions to serve rural communities.
4. **African Development Bank (AfDB) Africa Adaptation Acceleration Program:** AfDB supports projects that enhance access to credit for farmers involved in various agricultural value chains, promoting investments in postharvest handling, storage, and processing.

These international organizations and their initiatives play a crucial role in providing microcredit to farmers in Ethiopia, supporting agricultural development, and improving the livelihoods of rural communities.

Microfinance Institutions (MFIs) such as the Amhara Credit and Savings Institution (ACSI), Oromia Credit and Savings Share Company (OCSSCO), and Dedebit Credit and Savings Institution (DECSI) offer targeted loan products to farmers. These loans are designed to help with various aspects of farming, including the crucial stages of harvesting and postharvest handling.

Agricultural cooperatives are another key player in this sector. These cooperatives often provide loans to their members for postharvest handling and storage, helping to ensure that farmers can store their produce safely and market it at the right time to maximize their income.

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

1. **Oxfam Rural Savings and Credit Cooperatives (RUSACCOs):** Oxfam supports the establishment and strengthening of RUSACCOs, which provide microloans to farmers for agricultural inputs, equipment, and postharvest activities.
2. **CARE International Village Savings and Loan Associations (VSLAs**): CARE promotes VSLAs, which are community-based groups that provide savings and loan services to their members. These associations help farmers access microcredit for agricultural activities and small businesses.
3. **Farm Africa Access to Finance Program:** Farm Africa collaborates with local financial institutions to provide microloans to farmers. The program focuses on improving farmers' access to credit for purchasing inputs, adopting new technologies, and expanding their farming operations.
4. **Self Help Africa Microcredit for Smallholder Farmers:** The organization partners with local MFIs and cooperatives to provide microloans tailored to the needs of smallholder farmers. These loans are used for purchasing seeds, fertilizers, and other inputs, as well as for postharvest handling and storage.
5. **VisionFund Ethiopia Agricultural Microloans:** VisionFund offers microloans specifically designed for farmers to invest in agricultural inputs, equipment, and livestock. The organization also provides training in financial management and agricultural practices.
6. **Technoserve Agricultural Finance Program:** Technoserve works with local financial institutions to develop and offer microcredit products that meet the needs of smallholder farmers. The program includes capacity-building for farmers and financial institutions to ensure effective loan utilization and management.

Commercial banks also play a significant role in providing these loans. The Commercial Bank of Ethiopia (CBE), Dashen Bank, and Awash Bank offer loan products tailored to the needs of farmers.

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

To remove financial barriers in Ethiopia's agricultural sector, several strategic actions could be implemented, including:

- Enhancing training on finance accessibility and management
- Promoting common user facilities, such as community equipment and resources,
- Reducing high interest rates imposed on agricultural financing agencies.
- Creating awareness among farmers about available agricultural financial solutions can enable them to make informed decisions.

Provision of low-interest agricultural loans by financial institutions, possibly subsidized by the government, can alleviate the financial burden on farmers.

6.3.3 Suppliers of financial products and services

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

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

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

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

Financial partner	Comment
Commercial Bank of Ethiopia (CBE)	CBE is the largest commercial bank in Ethiopia and provides various financial services to the agricultural sector. It offers short-term and long-term loans for agricultural activities, including crop production, livestock, and agro processing.
Development Bank of Ethiopia (DBE)	DBE is a key player in financing agricultural projects in Ethiopia. It provides long-term loans for large-scale agricultural projects and agro-industries. The bank focuses on projects that align with the government's development plans.
Oromia Coop Bank (CBO)	CBO plays a significant role in financing the agricultural sector, particularly focusing on cooperatives and smallholder farmers. The bank provides loans, savings, and other financial services tailored to the agricultural community's needs.
Awash Bank	Awash Bank is one of the leading private banks in Ethiopia, offering a range of financial products and services for agricultural businesses. This includes loans for farmers, agribusinesses, and agro-industrial projects.
Dashen Bank	Dashen Bank provides credit facilities to the agricultural sector, supporting farmers, cooperatives, and agribusinesses. The bank offers various types of loans tailored to the agricultural sector's needs.

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

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

The approach taken in the financial model design is focused on strategically using grants to catalyse the development of the market for food loss reducing solutions (FL-RS). These financial mechanisms are designed to address the current market dynamics and challenges faced by smallholder farmers and agricultural MSMEs. The mechanisms do this by enhancing the supply and affordability of FL-RS, thus creating a self-sustaining market and reducing the need for continued programme support. Despite the potential benefits these models offer, there are several challenges that need to be addressed to ensure effective access and leveraging of FL-RS through financing. One of the primary challenges in accessing FL-RS is the high initial cost of these solutions. Smallholder farmers and agricultural MSMEs often operate with limited capital, making it difficult for them to invest in new technologies and equipment without substantial financial support. This high-cost barrier discourages adoption and limits market penetration. Another significant challenge is the lack of financial products tailored specifically to the agricultural sector. Many financial institutions are hesitant to develop and offer products for smallholder farmers and MSMEs due to perceived high risks and low profitability. Consequently, there is a scarcity of suitable financing options that can support the acquisition and implementation of FL-RS. Smallholder farmers and MSMEs often face difficulties in accessing credit due to stringent requirements set by financial institutions. These requirements typically include collateral, credit history,

and other financial credentials that many small-scale agricultural enterprises lack. Without access to credit, these enterprises cannot afford to invest in FL-RS, hampering efforts to reduce food loss.

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

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

The models developed to enhance adoption and uptake of FL-RS consists of (1) conditional procurement for smallholder farmers to reduce the cost of hermetic technology and drying sheets and (2) smart grants to reduce the cost and risk of providing loans to Agricultural MSME buying FL-R equipment and storage solutions.

6.4.1 Solutions for smallholder farmers (part of activity 2.2.1)

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

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

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

Below, is a detailed description of the operationalization of this solution:

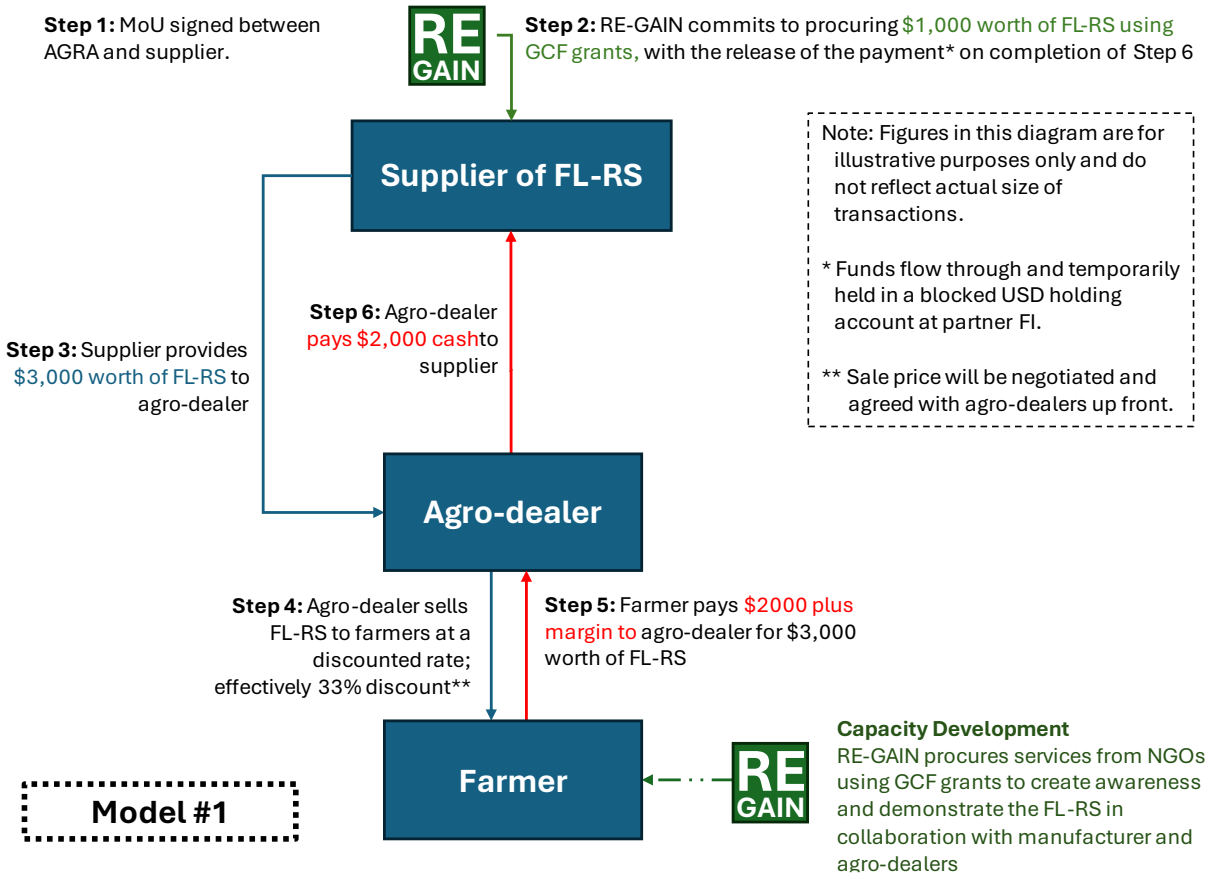


Figure 6-1 Model 1 for RE-GAIN Programme

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

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

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

Smallholder farmers then buy the FL-RS at the discounted rate. The agro-dealers subsequently makes payment to the manufacturer for two units for every one unit of the initial procurement from RE-GAIN (if not already paid on delivery). In cases

where an FI is not involved, this payment and a corresponding report trigger the release of the smart subsidy payment from RE-GAIN to the supplier. If an FI was involved, the release of the smart subsidy depends on the repayment of the loan.

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

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

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

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

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

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

6.4.1.2 Eligibility Criteria for Agricultural Traders, Processors, and Agrodealers

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

- Legal capacity to operate: Registration (and ability to produce registration certificate) as a sole trader, partnership, franchise, cooperative, or limited liability company in good order with the local tax authorities;
- If operating as an importer, evidence of compliance with import permits;

- If appropriate, demonstrated compliance with any Environmental standards or requirements to obtain licences or environmental impact assessments, reports or management plans as required by local laws;
- Proof of VAT registration;
- Preferably a track record of stocking and selling FL-RS as defined as part of the RE-GAIN programme preferably of the selected manufacturer or importer;
- Evidence of record keeping, including financial records;
- Willingness and financial capacity to stock hermetic technology at the right time (harvest);
- Presence in the target regions in the selected countries for the programme;
- Preferably engaging in the provision of additional services to small scale producers like moisture meters, training, credit and after sales services (aggregation, access to markets).

6.4.1.3 Eligibility Criteria for Smallholder Farmers and Communities

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

6.4.2 Solutions for Agricultural MSMEs

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

The primary objectives of Model 2 are twofold:

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

At the core of Model 2 is the engagement of local youth groups, poised to act as service providers for FL-RS, requiring high-cost equipment that can service multiple farmers. This includes harvesting machinery, mechanical multi-crop threshers and shellers (preferably solar-powered), moisture meters, and communal storage structures. The establishment of these service operations will be supported through business development initiatives, ensuring that youth groups have a solid foundation to provide reliable services. This approach leverages several key concepts to achieve the targeted benefits:

- Collectivism: By pooling resources, smallholder farmers benefit from economies of scale through cost sharing and increased bargaining power with off-takers, promoting further profitability and additional demand for FL-RS.

- **Post-harvest Handling:** Enhancing the quality and quantity of agricultural produce allows smallholder farmers to capture more value, thereby increasing their incomes.
- **Inclusion of Financiers:** Engaging financial institutions will unlock access to finance in a traditionally underserved market. The structure aims to reduce credit risk by providing a partial subsidy, which will lower borrowing costs due to the smaller loan size and reduced interest payments.

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

An overview of Model 2 is presented in

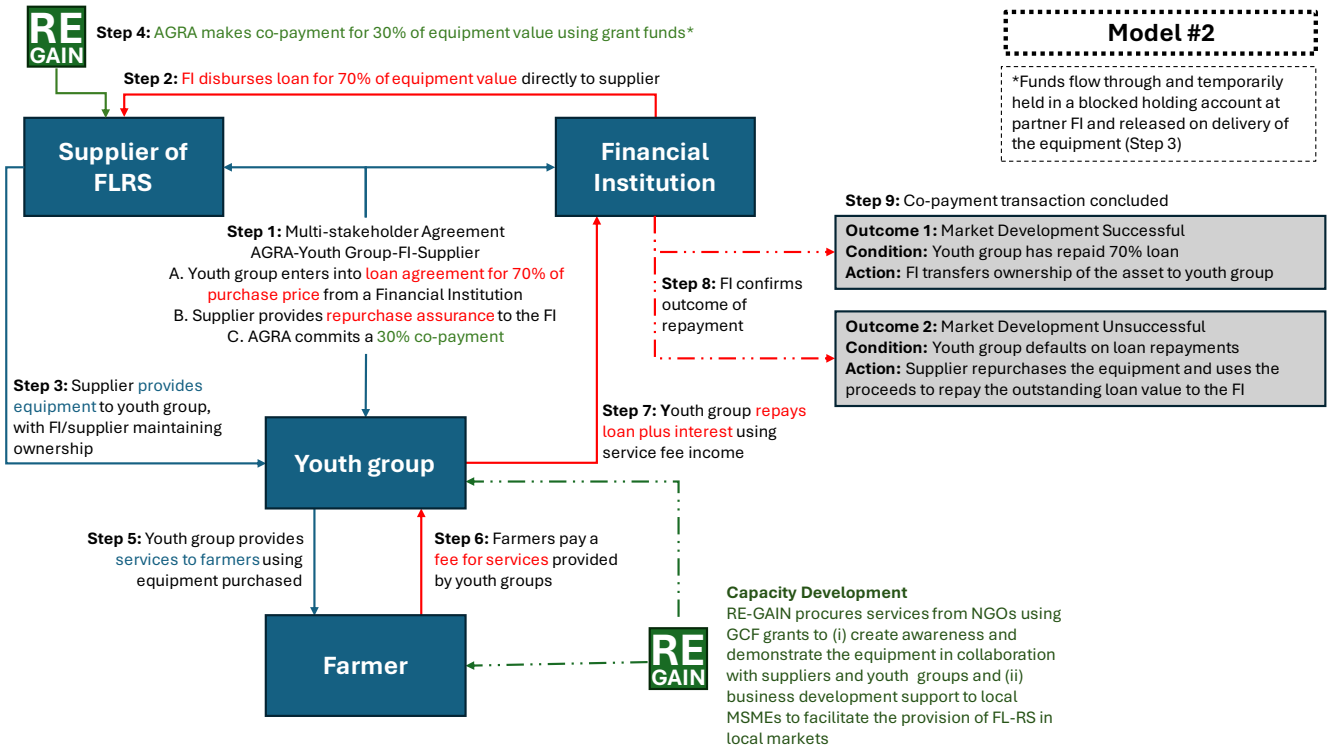


Figure 6-2, with detailed descriptions of each step in the following text. While RE-GAIN will facilitate the establishment of the entire process, its active involvement beyond Step 4, with ownership of Steps 5-9 transitioning to the three partners: youth groups, suppliers, and financial institutions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

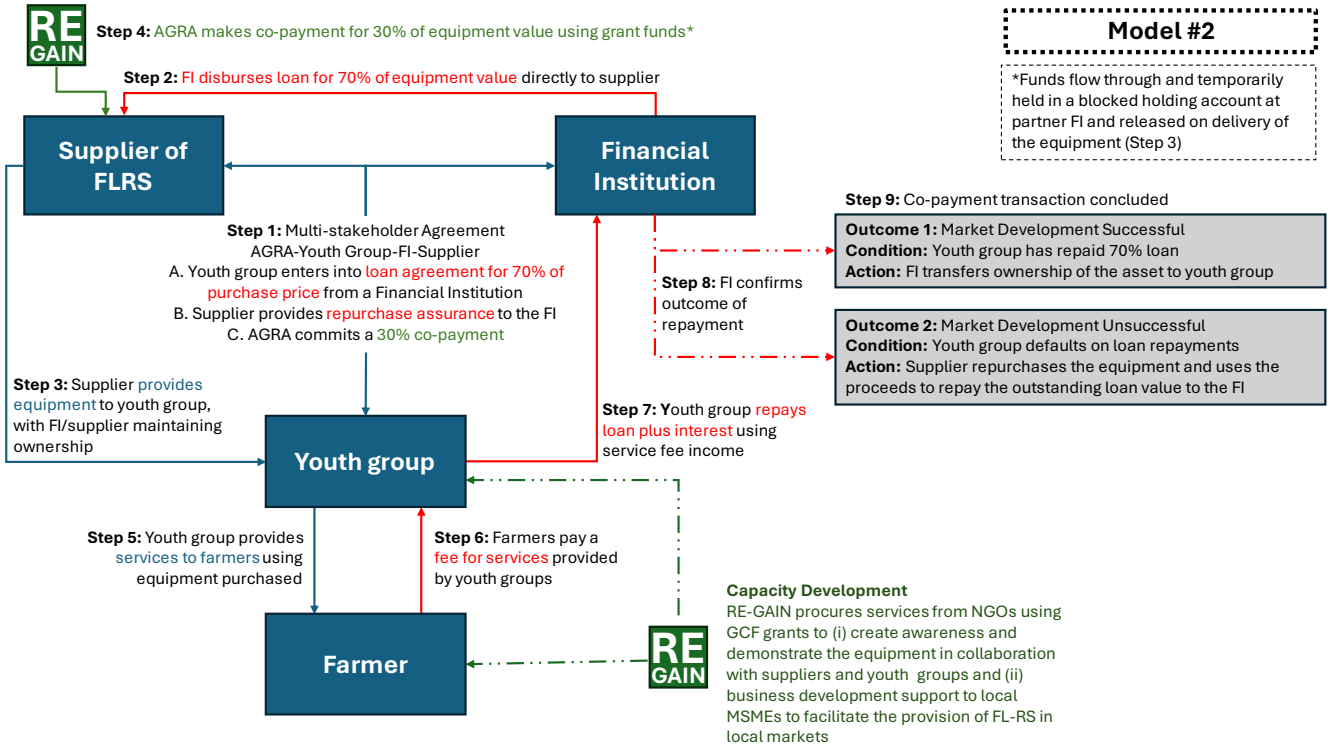


Figure 6-2 Model 2 for RE-GAIN programme

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

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

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

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

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

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

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

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

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

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

6.4.2.1 Eligibility Criteria for Supplier FL-RS for Equipment

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

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

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

6.4.2.2 Eligibility criteria for financial institutions

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

- Financial institutions must demonstrate they are licensed, regulated and supervised by the relevant authorities (Central Bank, MFI regulatory body, cooperative agency) and in compliance with any prudential liquidity requirements
- Experience and willingness to offer asset financing facilities of between USD 1.000 and USD 10.000 to equipment buyers and/or operators
- Willingness and ability to engage with Agricultural MSMEs or cooperatives and other key actors in the value chains; Willingness to open an escrow 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 Ethiopia 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 Ethiopia. The Ministry of Agriculture and Agricultural transformation Agency (ATA) will be the key partners, operating the extension services and several smallholder-oriented projects. The awareness campaign will aim for a maximum outreach and should use mass media, such as TV, radio and social media.

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

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

Organization	Description
Ministry of Agriculture of Ethiopia (MoA)	The MoA focuses on enhancing food security, improving market access, managing natural resources sustainably, and building resilience against climate change and disasters. Through these efforts, the MoA aims to promote sustainable agricultural practices, boost productivity, and improve the livelihoods of Ethiopian farmers.
FAO Ethiopia	FAO works with the Ethiopian government and local organizations to improve agricultural practices. Their programs offer training and resources on post-harvest management to reduce food losses and improve food security.
Agricultural Transformation Agency (ATA)	ATA is a government agency that partners with various stakeholders, including NGOs, to implement agricultural transformation initiatives. Its goal is to enhance productivity and food security through innovative and sustainable agricultural practices.
TechnoServe Ethiopia	TechnoServe provides business solutions to poverty by linking smallholder farmers with markets, improving value chains, and providing technical assistance to enhance agricultural productivity.
Ethiopian Farmers' Federation (EFF)	The EFF is an umbrella organization that represents the interests of Ethiopian farmers. It works to improve farmers' livelihoods through advocacy, capacity building, and promoting sustainable agricultural practices
Federation of Ethiopian Farmers' Cooperative Unions (FEFCU)	FEFCU represents various farmers' cooperative unions across Ethiopia. It focuses on improving agricultural productivity, marketing, and providing essential services to member cooperatives.

These organizations play a critical role in advancing Ethiopia'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 progrramme 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 Ethiopia:

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,	Strong collaboration with government entities and other programmes, leading to a more cohesive and impactful implementation process.

	share resources, and coordinate activities to maximize impact and avoid duplication of efforts.	

6.7 CONCLUSIONS ON THE MARKET STUDY

The proposed solutions at the RE-GAIN programme are not unknown in the Ethiopian 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 Ethiopia 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 Ethiopia, with significant losses within the harvest and post-harvest stages for key crops in the country; wheat and teff. 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 Ethiopia. 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 Ethiopia by addressing the key barriers identified during this phased study, as described in the image below:

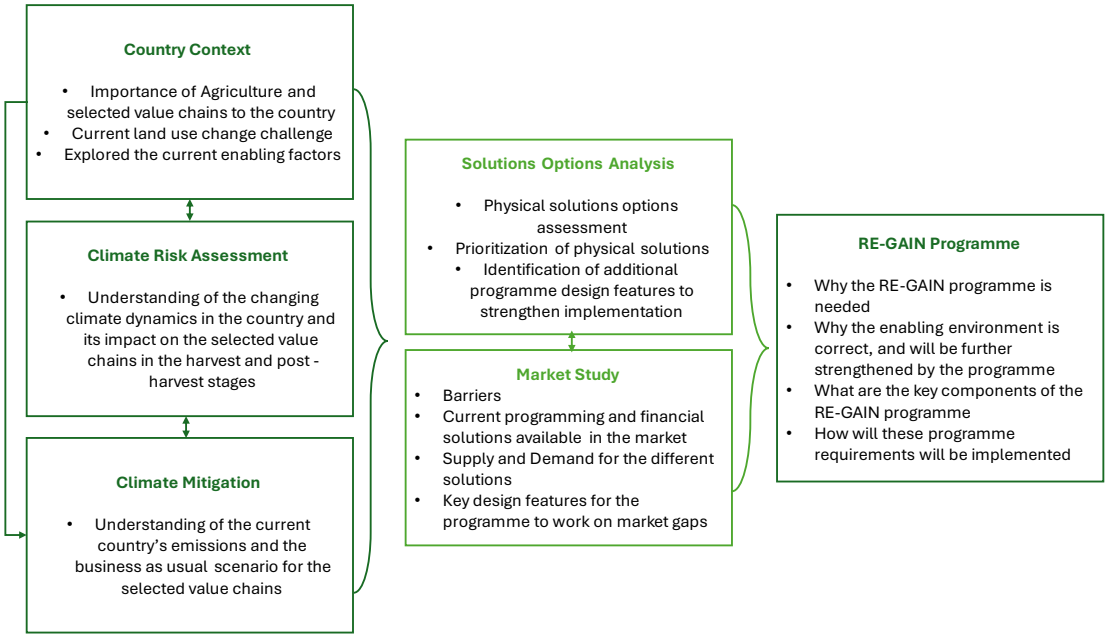


Figure 7-1 Content Summary of Feasibility Study for the RE-GAIN programme

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

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