ANNEX 3 – Part B

Economic Assessment

Version 3

2024

RE-GAIN: Scaling Solutions for Food Loss in Africa

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1 Introduction

To address the pressing need for broader implementation of solutions aimed at reducing climate-related harvest and post-harvest food loss, the proposed RE-GAIN 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, and facilitating the uptake of FL-RS by end users and service providers through a combination of policy levers, awareness raising and improved accessibility. 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 to foster 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 the development of programmatic 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.

This report presents an analysis of the costs and benefits and the economic rates of return associated with proposed project interventions in each of the seven countries and for the RE-GAIN programme as a whole. The process and criteria for selection of the countries and interventions is described further in the Feasibility Study (Annex 2). The interventions cover technologies (materials and equipment) for reducing post-harvest food losses as well as a series of 'soft' measures including awareness raising, capacity building, institutional strengthening, and financial assistance.

The underlying calculations of cost and benefit estimates are detailed in a cost-benefit analysis (CBA) model which is available as a separate Excel workbook (Annex 3 Economic Analysis). All assumptions and data sources are noted in the model, together with a number of explanatory notes. This report sets out:

- The approach to, and scope of the CBA (Section 2)
- Information on the costs of programme interventions, including sources of cost data and costing assumptions (Appendix A and Section 3)
- The nature and significance of anticipated benefits (primary and ancillary) resulting from the proposed interventions, including the methodologies used to quantify and value benefits where this was possible (Section 4).
- The outcomes of the CBA, represented in terms of key decision metrics (Net Present Value, Economic Internal Rate of Return and Benefit Cost Ratios), including an analysis of the sensitivity of the outcomes to changes in the underlying assumptions and important caveats and limitations to consider in the interpretation of the results (Section 5).

2 Approach

The aim of the CBA is to analyse the costs and benefits of the proposed interventions in each of the seven countries to be covered by the programme. The following key steps were applied in undertaking the CBA:

1. **Definition of an appropriate baseline (counterfactual) or 'without intervention' scenario against which the impacts of the proposed programme interventions can be compared over their lifetime**. The baseline recognises that the current situation will not remain static in the absence of the interventions given the influences of factors such as changes in climate, demography and socio-economic conditions. For the purposes of this study, food losses and associated impacts on livelihoods, health, and well-being in the absence of programme interventions are estimated using data from the most recent year available for each country and crop type as reported by the African Postharvest Losses Information System (APHLIS) (APHLIS, 2023). Given that the causes of post-harvest losses (PHL) are manifold, are locally-specific, and differ by crop-type, it was not possible to obtain quantitative estimates of how these losses are expected to change over the 10-year assessment period specifically as a result of climate change. However, the evidence is unequivocal that climate change stresses are already impacting food security through increasing temperatures, changing precipitation patterns, and greater frequency of some extreme events (IPCC, 2019). These climatic changes present substantial risks to food security in sub-Saharan Africa as a result of changes in both crop and livestock productivity, the changing distribution of pests and diseases, impacts on pollinators and associated impacts on food access (affordability), utilisation (safety and quality), and stability (regular supply) (Mbow, et al., 2019). In this light, by holding the rate of PHL constant over time under a 'no intervention' scenario, the economic analysis is considered likely to somewhat understate the impact and effectiveness of programme interventions.

2. **Estimation of the costs (including externality effects) associated with each of the types of interventions identified**. The analysis considers the whole life costs associated with each type of intervention including:
   - The capital costs of providing the necessary equipment and food loss reduction solutions (FL-RS) (physical interventions);
   - The costs of training, capacity building, technical and financial assistance, institutional strengthening, policy reform, monitoring, evaluation and learning (MEL) (non-physical interventions) which are needed to stimulate demand for, supply and widespread adoption of FL-RS; and
   - Any projected unintended environmental and social costs (negative externalities) associated with the implementation of the proposed interventions where these are foreseen, are significant (i.e. would have a discernible impact on the decision metrics (Net Present Value, Internal Rate of Return, or Benefit-Cost Ratio) and can be reliably quantified and valued.

   Estimates of the costs of programme interventions are described in Section 3.

3. **Estimation of the economic, social and environmental benefits of the proposed interventions.** The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) defines adaptation benefits as "the avoided damage costs or the accrued benefits following the adoption and implementation of adaptation measures". While many of the benefits are simply the averted losses and associated effects (e.g. on food security, nutrition, and GHGs) identified and quantified in step (a) above, some of the adaptation interventions also deliver important co-benefits such as food safety, employment, and protection of habitat for biodiversity and ecosystem services, which have been valued and factored into the analysis as far as possible. It should be noted that the nature and value of benefits from

the same adaptation intervention may differ from one country (and location within each country) to the next depending on, for example, existing vulnerability and the size of the beneficiary population and the physical and natural assets at risk. Benefits have been quantified and valued in monetary terms as far as possible and where it is proportionate to do so, based on a combination of the evidence and analysis presented elsewhere in the Feasibility Study (Annex 2), a review of the relevant literature, including datasets produced and/or collated by relevant international agencies and institutions (FAO, IFPRI, WHO, World Bank, etc), technical studies to inform the specification of cause-effect relationships ('production functions') and economic evidence used to inform the monetary valuation of impacts and effects. In cases where it has not been possible to quantify and value certain material benefits (e.g. where the detailed data necessary to derive estimates is not available), these benefits (and their likely significance) have been described in either quantitative (where possible) or qualitative terms.

The types of interventions being proposed are anticipated to give rise to a range of market and non-market benefits and co-benefits. Market benefits include, for example, increases in income associated with the availability and sale of more and better-quality produce, and opportunities for employment and other income-generating activities. Quantifiable market benefits have been valued using established market prices. Non-market benefits include avoided morbidity and mortality from malnutrition and fungal contamination of crops, and reduced impacts on ecosystems and the services and benefits they deliver such as carbon sequestration, water quality regulation, and provision of habitat for wildlife. These benefits are more challenging to value as they rely on scientific understanding and modelling of cause-effect relationships as well as an understanding of local preferences (demand) for the services and benefits in question. The non-market benefits have been quantified and valued as far as possible with reference to values derived in other studies in similar contexts elsewhere, where available and relevant.

4. **Discounting and application of the appropriate decision rules.** The costs and benefits have been estimated over a 10-year period, starting in 2025. Net benefits have been calculated as the difference between the 'with programme' and 'without programme' scenarios converted to measures of Economic Net Present Value (ENPV) and Economic Internal Rate of Return (EIRR) using the social discount rates (SDR) shown in Table 2-1 - for each country. Note that the effects of alternative discount rates (lower and higher than the base case) for each country have also been tested. A lower SDR has been applied for risk to life and health impacts. This is because the 'wealth effect', or diminishing marginal utility associated with higher incomes, does not apply as the welfare or utility associated with additional years of life will not decline as real incomes rise. The health discount rate associated with low- and low-middle-income countries of 5% (Markus Haacker, 2020) is used. Higher and lower discount rates of 7% and 3% respectively are assessed in the sensitivity analysis.

Table 2-1 -Social discount rates applied in each country

Country	Social Discount Rate	Source
Burkina Faso	Base case: 5% Range 5-12%	The base case rate (5%) which is also used in the 'best case' scenario, is the same as that used in GCF FP074 (for Burkina Faso) and which is based on the World Bank (2015) Guidelines on Discounting Costs and Benefits in Economic Analysis of World Bank Projects [online]. For the purposes of sensitivity testing, a rate of 12% has been applied in the 'worst case' scenario. The higher rate reflects the economic opportunity cost of capital used in a recent (2022) AfDB appraisal of the Integrated Maize, Soya bean, Poultry and Fish Value Chain Development and Resilience Building Project (PIMSAR) [see link to report].

Country	Social Discount Rate	Source
Ethiopia	Base case: 5% Range: 5-12%	The base case rate (5%) which is also used in the 'best case' scenario, is the same as that used in GCF FP136 (for Ethiopia). A 12% SDR was used in the 'worst case' scenario. This is consistent with that used in a World Bank appraisal of a proposed flood management project in Ethiopia in 2022 [see link to report] and was chosen to reflect promising growth prospects in the country.
Kenya	Base case: 11.5% Range: 9.9-12.7%	The SDRs applied for Kenya are based on guidance from the Ministry of National Treasury and Planning Kenya on National Parameters, Economic Opportunity Cost of Labor, Social Value of Time, and Commodity-Specific Conversion Factors for Public Project Appraisal (CRI, 2021). [online]. The base case SDR (11.5%) is not dissimilar to the 12% SDR for Kenya used in GCF FP175 for Kenya.
Malawi	Base case: 10% Range: 8-10%	The base case and best case SDR is the same as that used in GCF FP002 which is based on the cost of capital in Malawi. Robinson et al recommend the real SDR should be two times the short term projected real per capita growth rate, which is around 4% in the UN's middle-of-the-road scenario for Malawi (2020). An 8% discount rate has therefore been used as a lower-bound estimate and applied in the 'worst case' scenario.
Tanzania	Base case: 6.2% Range: 6.2-10%	The base case and 'best case' SDR is based on the rate used in GCF FP218 (UNEP) and which is close to the 6% rate used by the World Bank in an appraisal of a Sustainable Agricultural Intensification Project in 2018. The 'worst case' SDR for Tanzania is taken from a World Bank Appraisal for a Resilient Natural Resources Project [see link to report].
Uganda	Base case: 8% Range: 5-12%	The base case discount rate (8%) is the same used in recent World Bank appraisals for irrigation and forestry projects in Uganda. This is lower than the 12% previously recommended by NEMA (2012) which is used for the purposes of sensitivity testing in the 'worst case' scenario.
Zambia	Base case: 10% Range: 5-10%	The base case (and 'worst case') SDR is the same as that used in GCF FP072, covering Zambia, as recommended in UNDP (2015). An SDR of 5% has been applied in the 'best case' scenario following the World Bank (2015) Guidelines on Discounting Costs and Benefits in Economic Analysis of World Bank Projects

5. **Sensitivity analysis.** Sensitivity analysis has been performed to test the sensitivity of the outcomes to changes in the underlying assumptions, focusing on key input variables with large uncertainties. These include the discount rate, the shadow price of carbon, the potential food loss reductions that can be achieved by each technology for each crop type in each country, the size of the premium that farmers may earn on the price of higher quality crops, and the proportion of baseline production that can potentially earn a premium as a result of quality and safety improvements from FL-RS.

3 Costs of interventions

3.1 SCOPE

The scope of the proposed programme activities encompasses a suite of physical and non-physical interventions which, together, are intended to stimulate the demand for and supply of FL-RS solutions; leverage extension services to close knowledge gaps to more effective usage of FL-RS for the purposes of enhancing climate resilience, as well as improve the enabling environment to maximise the impact and sustainability of the programme interventions once the period of programme funding has ended.

The specific activities to be undertaken across the seven countries are described in detail in Section B.3. of the full Funding Proposal and in Annex 2. They are structured across five outputs under three components as shown in the table below.

Table 3-1 -Scope of programme activities costed in the economic analysis

Component	Outputs	Activities
1 – FL-RS demand-side development to increase the adoption of FL-RS by farmers	Output 1.1. Smallholder farmers supported to adopt FL-RSAdaptation of existing food loss technologies to CC	• Gender-responsive awareness raising, demonstration & knowledge & technology transfer for the use of weather/climate information, FL-RS and related practices • Support to the immediate availability of identified FL-RS options
	Output 1.2. Improved market linkages between agri-value chain actors	• Facilitate market linkages between institutional markets & other buyers & smallholders, MSMEs considering existing constraints faced by women in the sector • Support to structuring of value chains & coordination between market actors
2 – FL-RS supply-side development to increase availability and affordability of FL-RS	Output 2.1. Business development support for the improved provision of FL-RS on local markets	• Provide business development support & market intelligence • 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 2.2. Financial mechanisms for smallholders and MSMEs to support the adoption of FL-RS	• 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 or catalytic grant models, as well as 'lease-to-own models for FL-RS focussing on women and youth as key beneficiaries.
3 – Enabling environment to ensure sustainability of the FL-RS market	Output 3.1. Enhanced capacity of national institutions to enable investments in FL-RS	• Support the revision of polices in support of enabling FL-RS investments, including tax exemptions, certification and standards for FL-RS quality • Promote successful FL-RS business models for scaling-up & replication

3.2 PROGRAMME BUDGET AND COST ESTIMATIONS

The total cost of the program is US$ 105 million, comprising US$ 97.41 million in core programme costs and US$ 5.53 million in programme management, monitoring and evaluation costs. It is proposed that US$ 69.79 million (72%) of the core programme costs as well as the programme management costs will be covered by the GCF, with AGRA contributing US$ 27.66 million (28%).

The costs associated with each of the activities is shown in the detailed budget plan (Annex 4). The breakdown of costs for programme implementation used in the economic analysis are the same as those detailed in the budget plan (Annex 4) and the financial analysis (Annex 3A). The cost estimates for the proposed activities in the programme logframe have been derived from a combination of existing AGRA programmes wherever possible. When no existing programme provides a precedent, AGRA's expert opinion has been used, drawing from similar programmes.

3.2.1 Cost by component

The costs of each of the components are shown in Table 3-2.

Table 3-2 - Programme cost by component

Component			Cost (US$, millions)
1	Food Loss-Reduction Solutions (FL-RS) demand side development to increase the adoption of FL-RS by farmers		42.74
2	FL-RS supply side development to increase availability and affordability of FL-RS .	Equipment co-payment	36.98
		Technical capacity	6.41
3	Enabling environment to ensure sustainability of the FL-RS market		11.34
Programme Management and Monitoring & Evaluation	Monitoring & Evaluation		2.50
	Programme Management		5.03
	Total		**105.00**

3.2.2 Cost by country and year

It is assumed that programme expenditures are incurred over the first five years of the programme (the period of programme implementation), with physical interventions (FL-RS) starting in 2025. The approximate allocation of investment for each of the physical and non-physical interventions over this period is shown in
Table 3-3.

Table 3-3 - Expenditure profile

Year	Physical interventions	Non-physical interventions
1	20%	10%
2	30%	27%
3	30%	27%
4	20%	27%
5	0%	10%

The resulting profile of costs including programme management costs over the 10-year programme duration and total costs for each country are shown in the tables below.

Table 3-4: Programme costs by country by year over years 1-5 (US$ millions)

Country	Year 1	Year 2	Year 3	Year 4	Year 5	TOTAL
Burkina Faso	3.20	3.66	3.51	3.06	1.43	14.85
Ethiopia	3.19	3.68	3.61	3.22	1.51	15.21
Kenya	3.18	3.64	3.50	3.08	1.44	14.85
Malawi	3.08	3.57	3.56	3.24	1.48	14.93
Tanzania	3.18	3.63	3.50	3.09	1.45	14.84
Uganda	3.18	3.63	3.50	3.12	1.52	14.95
Zambia	3.28	3.74	3.61	3.20	1.55	15.37
Total	22.28	25.54	24.79	22.01	10.38	105.00

3.2.3 Costs of physical interventions in Component 2

The cost per intervention is based off market research and represents the market value in that country at the time of modelling (Table 3-5).

Table 3-5 - Physical intervention market value in US$ per unit

Intervention	Burkina Faso	Ethiopia	Kenya	Malawi	Tanzania	Uganda	Zambia
Metal and plastic silos	15,000	20,000	15,000	20,000	15,000	20,000	15,000
Mechanical multi-crop thrashers	4,000	4,000	4,000	4,000	4,000	3,800	4,000
Moisture meter	100	100	100	150	100	100	100
Communal storage structures	200	200	200	200	200	200	200
Storage protectants and control	20	20	20	20	20	20	20
Tarpaulins and plastic sheets	25	25	40	35	30	35	35
Hermetic bags	2	2	2	2	2	2	2

Using information on the number of smallholder farmer households to be targeted, the total number of units expected to be mobilized in each country is shown in Table 3-6. Note that some of the solutions such as metal and plastic silos, communal storage structures, moisture meters, threshers and storage protectants and control would be shared between groups of households.

Table 3-6 - Number of each type of FL-RS to be mobilized in each country directly through the programme over the 5-year implementation period

FL-RS type	Burkina Faso	Ethiopia	Kenya	Malawi	Tanzania	Uganda	Zambia
Metal and plastic silos	426	338	458	273	567	478	350
Mechanical multi-crop thrashers	160	127	172	102	213	179	131
Tarpaulins and plastic sheets	319,225	253,366	343,498	204,868	425,518	358,612	262,187
Moisture meters	319	253	343	205	426	359	262
Communal storage structures	160	127	172	102	213	179	131

Storage protectants and control agents	319	253	343	205	426	359	262
Hermetic bags	425,634	380,049	858,746	307,302	1,063,794	896,529	393,280

The average lifespan of the FL-RS ranges between two years (for hermetic bags, moisture meters, and storage protectants) to five years for silos and communal storage structures. Information on the average lifespan of equipment is combined with the mobilization rate (Table 3-8) to derive an estimate of the number of units of each type in operation in each country over the 10-year assessment period which then also determines the benefit flows.

4 Benefits of proposed interventions to reduce food loss

4.1 CONTEXT

4.1.1 Impacts of climate change on food loss

Agriculture-based livelihood systems such as those in Sub-Saharan Africa (SSA) are especially vulnerable to the adverse effects of climate change (Chegere, 2018). Climate change is expected to have a profound impact on agricultural productivity, postharvest losses and value chains. A changing climate will affect agricultural productivity both directly by introducing changes in agro-ecological conditions, such as drought, variable precipitation, extreme weather events; and indirectly, by giving rise to new diseases and pests. These risks are compounded in SSA by inadequate post-harvest handling practices and inadequate facilities and infrastructure (Chegere, 2018). Increases in mean surface temperature will also cause a further loss of productive land and decreases crop productivity, which together with post-harvest losses, will threaten regional food security (APHLIS, 2023).

4.1.2 The impact of food loss on the climate

According to the Food and Agriculture Organization of the United Nations (FAO), around 13.23 percent of food produced in 2021 was lost from the post-harvest stage up to, but excluding, the retail stage at the global scale (FAO, 2023). In Sub-Saharan Africa, PHL are substantially higher, estimated to be around 19.95%. On average, the global food waste carbon footprint has been assessed between 3.3 Gigatons (Gt) of CO2 equivalent (CO_2e) each year, representing 6% of global GHG emissions. Considering associated GHG emissions related to land use change, deforestation and organic soils management, this total reaches over 4.4 Gt of CO2-eq or 8% of total anthropogenic GHG emissions (Amicarelli, Lagioia, & Bux, 2021). The mitigation potential of avoided food loss is therefore substantial, with significant associated co-benefits in terms of food security and land use change.

4.1.3 Objectives of the proposed interventions

In light of the above, and as described in detail in the Funding Proposal, the proposed programme is designed are to raise awareness and build capacity to promote the adoption of 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.

More specifically, the objectives of the programme are to:

- Improve **food security.** Reducing food loss increases the overall quantity of food available which can reduce the need to supplement availability through transfer programs (at household level) or via commercial imports or food aid donations (at national level). An increased food supply, under normal circumstances, should also translate into a reduction in prices for consumers, improving overall access. Retention of inferior quality products, those most likely to be lost currently, could disproportionately benefit the poor where there are price discounts associated with lower quality food (Kadjo et al., 2016). PHL reduction in the form of food quality, for example due to vitamin or protein decay, can improve food utilization (nutrition) among consumers. An increase in retained food can be especially important seasonally in places where the prices of storable staples commonly increase sharply several months after the harvest period, by improving access precisely when seasonally food insecure households most need it and by providing stability (Sheahan & Barrett, 2017).
- Improve **food safety**, as distinct from food security. While substantial quantities of food are removed from the system as a result of its quality not meeting the standards considered acceptable or safe for human consumption, there are also

instances where spoilage or contamination is not perceptible to the human senses and goes undetected, leading to adverse health effects when food is consumed. Mycotoxins, in the forms of fumonisin and aflatoxins, can lead to slow-developing esophageal and liver cancers (respectively) and are growth-retarding and immuno-suppressive even in doses well-short of the more sensational, and often deadly, acute aflatoxicosis. These food safety concerns, arising from fungal or pest infestations, have major disease and global health implications (Sheahan & Barrett, 2017).

- **Reduce unnecessary resource use**. These resources come in the form of on-farm inputs that pose sustainability challenges, including water, chemical fertilizer, agrochemicals, labour, and land. Anticipated PHL by farmers may mean that more of these resources are used than is necessary to meet production or consumption targets. Reducing PHL and, thereby, creating a longer term incentive for farmers to use complementary resources more effectively and efficiently, could ultimately lead to a reduction in the use of scarce resources. Similar arguments apply to the post-harvest value chain, where reduced PHL could, in principle, reduce fuel costs, transport-related pollution, energy consumption in processing, etc. Not only might limiting input use result in environmental or human health benefits, but it should also reduce costs for farmers, traders, processors, and other actors in food value chains, potentially leading to an increase in profits and a decrease in consumer food prices (Sheahan & Barrett, 2017).
- **Increase profits for food value chain actors**. The private sector, including smallholder farmers, plays a critical role in making food available to consumers and, at levels above the farmer, establishing a supply chain for producers to utilize. The vast majority of food flows through commercial, not government or non-profit, channels in SSA. Insofar as profit is a natural objective of commercial entities, reducing waste and thereby cost holds natural appeal to private actors in food value chains. In SSA, PHL reduction could mean improving the livelihoods of both smallholder farmers and large-scale agribusinesses. Indeed, recognizing this natural profit motive to reduce PHL that is intrinsic to virtually all actors in food systems in SSA (and elsewhere) is essential to a clear understanding of the likely benefits to direct interventions that reduce PHL. For the most part, with the partial exception of food safety considerations, private sector actors have a strong material incentive to reduce PHL for their own revenue and profit maximization goals (Sheahan & Barrett, 2017). Furthermore, there is evidence from multiple countries that agri-processing industries are operating far below their capacities. This is due largely to the lack of both volume and quality of raw materials, as large quantities of raw materials are rejected as being unsafe for either human or animal consumption. Improvements in quality, in addition to raising the throughput and profitability of agro-processors, also allows farmers to fetch better prices for the higher quality produce.

4.1.4 Benefits included in the economic assessment

The proposed programme activities have been specifically designed to achieve these objectives and the ultimate outcomes of improving food and nutritional security and enhancing the resilience of smallholder farmers to the effects of a changing climate.

The scope of the benefits assessment has been determined through the mapping of a series of impact pathways associated with implementation of the interventions, accounting for positive and negative externalities (unintended impacts) as shown in the figure below.

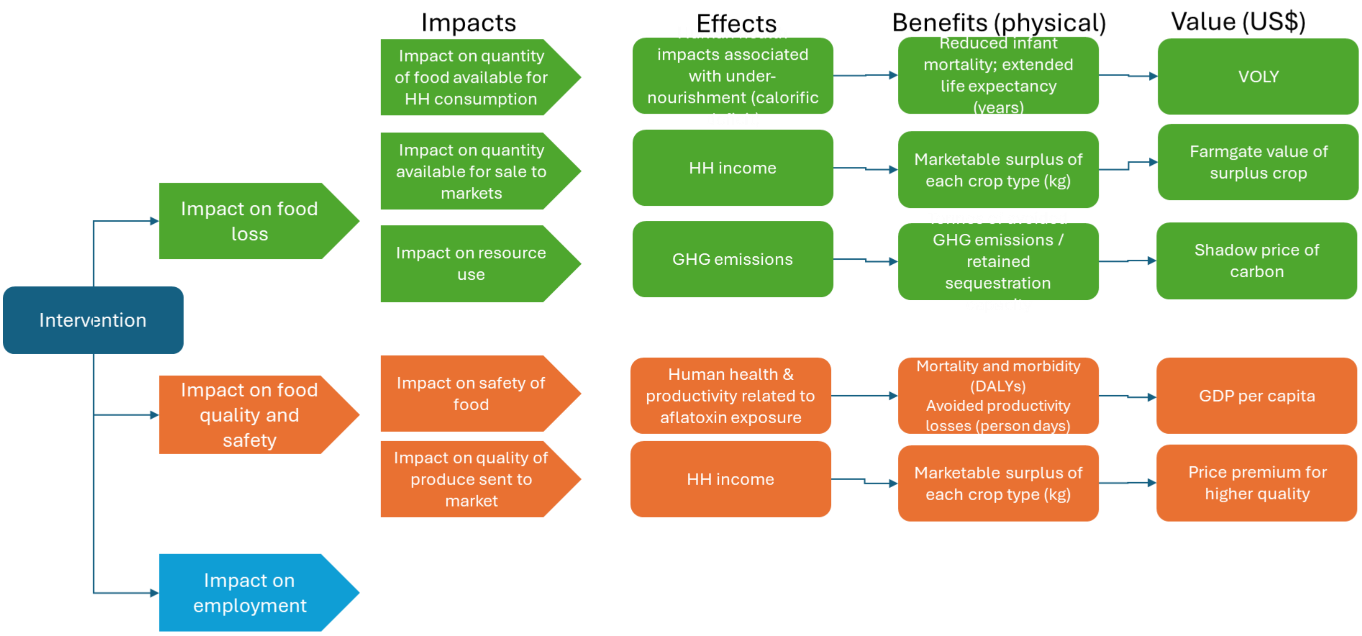


Figure 4-1 - Impact pathways

The approaches for quantifying and valuing each of these benefits are described in more detail in the sections that follow.

4.2 FOOD SECURITY AND IMPACTS ON HUMAN HEALTH AND WELL-BEING

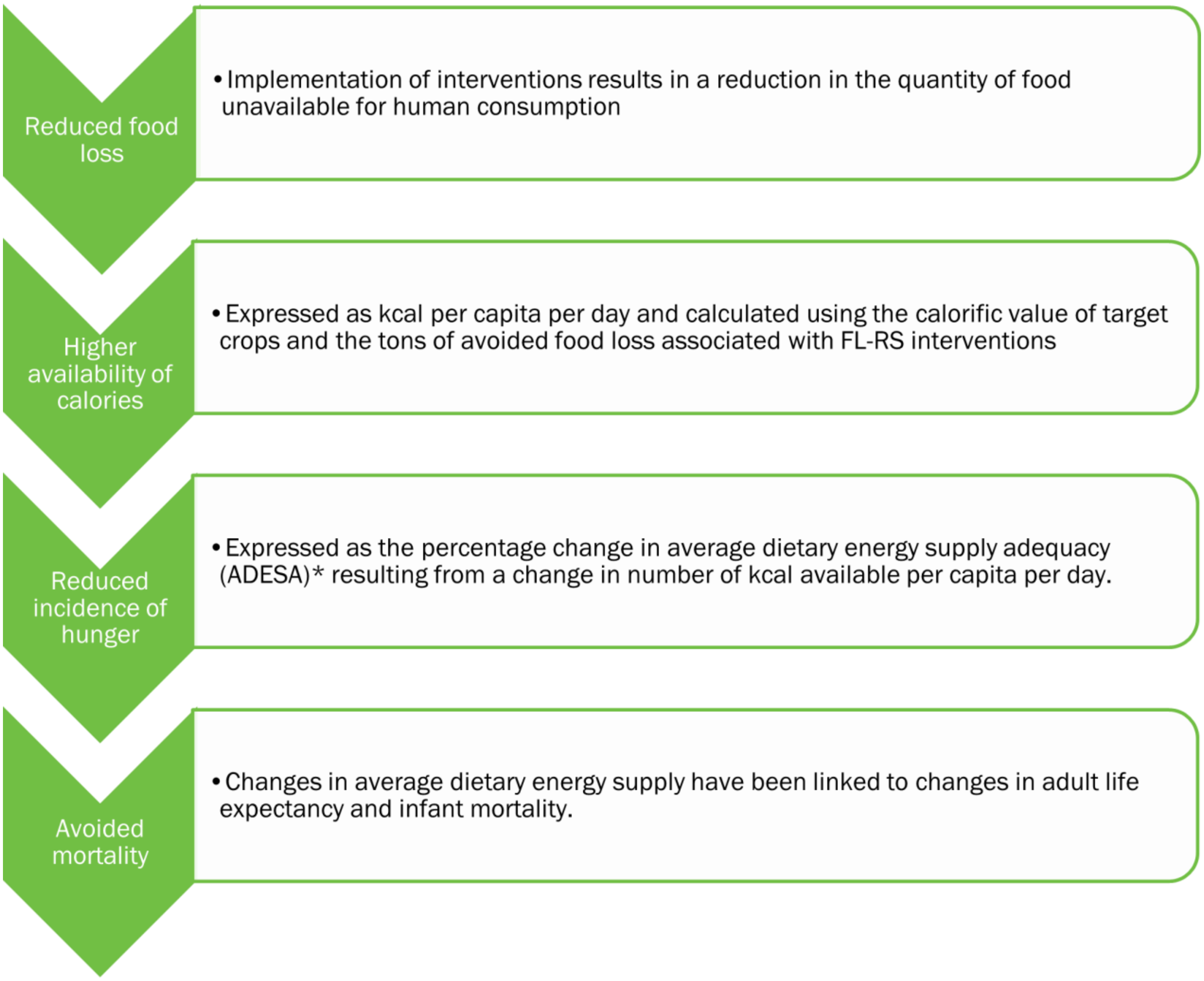
4.2.1 Context

Food insecurity and undernourishment have negative effects that flow from the household, to the broader economy and to future generations. Sub-optimal calorific and micronutrient intake in adults has been linked to poorer subjective well-being, lower wages and lower economic growth. Undernourishment also impacts health outcomes, leading to higher mortality and morbidity (National Planning Commission, 2021). Food insecurity and undernourishment are prevalent in the seven African countries targeted. In the absence of interventions, the number of individuals subject to food insecurity and undernourishment is likely to increase in the face of rapidly growing populations and worsening climate impacts – including impacts on the availability and productivity of agricultural land and increased levels of food loss due to pests and disease.

4.2.2 Benefits of measures

The proposed programme will contribute to food security in seven African countries by promoting the wide-scale adoption of FL-RS among smallholder farmers. While climate change is known to impact the full spectrum of food systems — from production through to consumption — the proposed programme's focus on post-harvest food loss addresses a critical, but somewhat under-served, component of food security. In addition to increasing the amount of food available for consumption due to reduced losses, this approach will also improve the quality of produce leaving the farms, thereby increasing nutritional value, marketability and income potential, while simultaneously reducing the substantial GHG emissions associated with food loss. This will not only benefit individuals, but a more stable food supply will enhance public health systems through reduced incidence of nutrition-related illness.

The impact pathway leading to improvements in food security is as follows:



* ADESA expresses Dietary Energy Supply (DES) as a percentage of the Average Dietary Energy Requirement (ADER).

The relationship between undernourishment (calorific deficit) and mortality is based on the findings of a recent study that examined the impact of food insecurity on health outcomes using empirical evidence from sub-Saharan African countries (Beyene, 2023). The study was conducted for the whole population of 31 sampled countries selected based on data availability. Using secondary data collected from the online databases of the UNDP, FAO, and the World Bank, the study combined multi-country panel data analysis with several estimation techniques to investigate the impact of food insecurity on life expectancy and infant mortality. The findings suggest that:

- Life expectancy rises by 0.00317 PPs with every 1% increase in average dietary energy supply
- Infant mortality reduces by 0.0139 PPs with every 1% increase in average dietary energy supply

It has not been possible to quantify the benefits of FL-RS interventions in terms of improved nutrition. While the literature search revealed one study that estimates the reductions in disability adjusted life years (DALYs) associated with avoided child wasting and nutritional deficiencies for Ethiopia (National Planning Commission, 2021), it was not possible to reliably replicate this approach across other countries given a lack of data across the target countries. Moreover, the time and effort it would take to do so is considered disproportionate to the size (value) of the effect that it would produce. Satisfying human nutritional needs requires regular intake of a wide range of nutrients from a diverse range of food crops. However, promoting diversification of crop production and diet is not a priority for the proposed programme. Second order effects, such as on public health systems, have also not been accounted for due to methodological complexity.

4.2.3 Valuation basis

Estimates of the food loss reductions resulting from the implementation of programme interventions have been derived using information on:

- The cultivated areas, production and average yield of the different crops grown by smallholder farmers in each of the target countries, based on information from national annual agricultural surveys, census data, FAO data, the Global Data Lab and bespoke studies. Further information on the specific sources used for each country is documented in the Excel model.
- The number of beneficiaries in each country
- The average food losses incurred at each stage of the value chain for each crop in each country at present (in the absence of intervention), based on data available from several sources, with highest priority given to data from the African Postharvest Losses Information System (APHLIS). Where APHILIS did not have data available on losses for a specific country, crop and value chain stage, the FAO Food Loss and Waste Database was the second priority data source. Where data were not available for a target country or crop, estimates from neighbouring countries were used. If any other estimate was used, these are specified per country/crop and documented in the Excel model.
- The effectiveness of different FL-RS at reducing food losses at each stage of the value chain based on a review of the available literature. These estimates, like each of those listed above, were extracted directly from the mitigation model (Annex 22). The savings per crop per year for each year of the assessment period were then calculated.
- The calorific value of the avoided PHLs for each crop was estimated using information from Food Composition tables (FAO, n.d.)from the FAO Food Balance Sheets handbook (FAO, 2001) and used to calculate the additional kilocalories available per capita as a result of food loss reductions.
- This was added to the average dietary energy supply (from the FAO's Food Security Indicators) of each country to provide an indication of the extent to which the additional calories close the gap between dietary energy requirements and supply. While the national statistics show that the average dietary energy supply in each country exceeds requirements in Burkina Faso, Ethiopia, Malawi, and Tanzania, these averages mask differences in supply across segments of the population within countries. It is therefore assumed that increasing the availability of food within the targeted communities will make an important contribution to addressing localised deficits.

We have used the value of a statistical life (VSLY) to capture the benefits yielded by changes in life expectancy and infant mortality. This is the most common method used for representing the value of a life. It reflects the amount of money that a person or society is realistically willing to pay to save one human life. We have taken a human capital approach given its usefulness in estimating the future earnings which may result from health improvements which extend lives.

Specifically, we have adopted the WHO-recommended three times per-capita income VSLY threshold for health interventions in sub-Saharan Africa. Whilst this figure is considered an underestimate in some specific national contexts – e.g. Tanzania where a VSLY equivalent to 4.5 times per-capita income has been estimated (Patenaude, Semali, Killewo, & Barnighausen, 2019) – we have adopted the WHO threshold as a conservative estimate that can be applied across all seven target countries and which is widely accepted and considered appropriate for use in cost-benefit analysis (Franklin, 2023).

The following formula is employed to estimate the economic value of additional life years resulting from increased food security into USD equivalents:

*Economic value of increased food security = number of years of additional life gained through extensions in life expectancy and reductions in infant mortality * VSLY (3x GDP/capita)*

A detailed overview of input assumptions and data sources used in the valuation approach is presented in the accompanying Excel-based CBA. The key underlying assumptions can be summarised as follows:

- Mortality reduction factors are for all of SSA and assumed to be constant overtime.
- Baseline dietary energy requirements and supply are assumed to remain constant overtime.

- Each additional percentage point of ADESA is assumed to yield the same increase in life expectancy/reduction in infant mortality as the prior (i.e. the marginal returns do not diminish with each increment of ADESA).
- Recent UN projections (UN Department of Economic and Social Affairs: Population Division, 2024) are used to provide data on population, total births, life expectancy at birth, and infant mortality.
- GDP per capita data is based on World Bank indicators (World Bank Group, n.d.) and projected using 10 year average GDP capita growth rates. Data on dietary energy supply (FAO, 2024) and calorific values (FAO, n.d.) is provided by FAO.

4.2.4 Results

The resulting present values of the human health benefits associated with the reduction in food losses resulting from the implementation of programme activities are shown in Table 4-1. The 'worst' and 'best' case scenarios have been defined for the purposes of sensitivity testing to reflect the end points of the range and specifically by varying assumptions regarding the efficacy of the equipment adopted by households (reflected in the percentage of food loss reduction achieved).

Table 4-1 - Present value of benefits of improved food security on human health (US$ millions)

Country	Base	Worst case	Best case
Burkina Faso	0.31	0.17	0.57
Ethiopia	0.63	0.52	1.82
Kenya	1.07	0.45	1.55
Malawi	0.90	0.38	1.30
Tanzania	2.49	1.05	3.60
Uganda	1.43	0.61	2.08
Zambia	2.66	1.12	3.84

4.3 HEALTH-RELATED ECONOMIC IMPACTS OF CONTAMINATION

4.3.1 Context

Approximately a quarter of the world's agricultural commodities are contaminated by mycotoxins, leading to nearly one billion tons of food loss annually (FAO, n.d.). Among these, aflatoxins are of particular concern due to their high toxicity, which poses serious risks to human health and results in significant economic losses from contaminated staple crops.

Aflatoxins are highly toxic, odourless, colourless, and flavourless toxins produced by the *Aspergillus* fungi. Due to their severe toxicity to both humans and animals, many countries (especially in the European Union and United States) have implemented strict limits on the permissible levels of aflatoxins in food and animal feed. However, in many countries, either regulatory limits on aflatoxins are not in place, or there is insufficient capacity to enforce such regulations. These toxins are most prevalent in tropical and subtropical regions, where heat and humidity promote the growth of *Aspergillus* fungi, both pre- and post-harvest. Aflatoxins commonly affect staple crops such as maize, groundnuts, cereals, legumes, tree nuts, and spices, with maize and groundnuts being especially susceptible due to their high consumption rates.

The literature on the economics of mycotoxins identifies two broad impacts (Pitt, 2012) (Vardon P, 2003) (Lubulwa ASG, 1994) (Highley E, 1994):

i. the direct market costs associated with lost trade or reduced revenues due to contaminated food or feed. Losses related to markets occur within systems in which mycotoxins are being monitored in the food and feed supply. Food that has mycotoxin levels above a particular maximum allowable level is either rejected outright for sale or sold at a lower price for a different use. Such transactions can take place at local levels or at the level of trade among countries.

ii. the human health losses from adverse effects associated with mycotoxin consumption. Losses related to health occur when mycotoxins are present in food at levels that can cause illness. In developed countries, such losses are often measured in terms of cost of illness; around the world, such losses are more frequently measured in terms of disability adjusted life years (DALYs).

Following a systematic literature review of the aflatoxin situation in Africa, Meijer, N. et al (Meijer, 2018) concluded that, in general, there is little evidence in literature on the economic effects of aflatoxins contamination. This is attributed to both the costs of collecting the data necessary to measure impact (including the epidemiology, medication costs, etc which may not be readily available in many African countries) and the complexity of the economic analysis required.

The trade-related impact of aflatoxin contamination is mainly evaluated from the perspective of aflatoxin regulation (primarily EU legal limits) affecting the export of commodities from developing countries, including Africa. The cost of mycotoxins to a particular commodity group is typically assessed by estimating how much of the commodity must be discarded or discounted due to mycotoxin contamination. Initial estimates suggested that meeting the EU standards, implemented in 2002, would decrease African exports by 64% or USD670 million (2001 prices). However, subsequent analyses (Narayan, 2014) (F., 2004) have shown the losses to be much lower because trade between Africa and the EU was not as large as originally estimated and most of the issues were related to crops for domestic consumption (food, feed and re-planting) with only a negligible percentage for export. Trade impacts have been estimated in various ways, including econometric and explanatory approaches, with their results depending on the specific analytical methods, data and assumptions used. **It is therefore not possible to draw strong conclusions on the trade-related impacts of aflatoxin regulations for African exporters** and thus no attempt has been made to do so here.

At a country-level, most economic impact studies have focused on the losses borne by producers from lower productivity due to aflatoxin-contaminated feed and discarded produce, or from the additional costs of efforts by farmers to reduce aflatoxin contamination. Most studies have been conducted in the Kenyan dairy chain (Meijer et al, 2018) and therefore the findings have limited application to crops grown elsewhere. For this reason, the firm-level impacts have not been considered further here.

Meijer et al (2018) found no peer-reviewed scientific publications on health-related economic impacts for African countries, although several studies exist in grey literature (e.g. project reports) that quantify the economic losses due to aflatoxin-related public health problems, particularly for liver cancer, in terms of disability adjusted life years (DALYs) and the value of a statistical life (VSL).

Evaluating the human health economic impacts of mycotoxins is crucial to understanding their total economic impact because mycotoxins primarily affect lower income countries, where trade related losses are not nearly as prominent as adverse health effects from consuming food contaminated with mycotoxins (Pitt, 2012). In conditions of drought or food insecurity (both of which may become more prevalent in light of a changing climate), subsistence farmers and local food traders often have little choice but to eat contaminated food.

Chronic exposure to aflatoxins can lead to serious health issues, including liver cancer, particularly hepatocellular carcinoma (HCC), which is the fourth most common cancer in sub-Saharan Africa. The risk of HCC is significantly higher in areas with high levels of hepatitis B virus (HBV) exposure, where aflatoxin exposure can increase the risk of developing HCC by thirty times (Liu Y, 2010). Aflatoxins also weaken the immune system, worsen conditions such as hepatitis B and HIV/AIDS, and are associated with child stunting (FAO, n.d.). Acute exposure to extremely high levels of aflatoxins can result in death, as seen in Kenya, where contaminated maize with aflatoxin levels ranging from more than 20 parts per billion (ppb) to over 1,000 ppb caused 125 deaths and hundreds of illnesses (Lewis L, 2005).

These aflatoxin-induced health impacts are expected to continue (or indeed increase due to the exacerbating effects of climate change) without targeted interventions, resulting in rising mortality, morbidity and lost economic productivity. Aflatoxins tend to contaminate plants that have already been compromised by factors like drought or pest damage. As a result, adhering to good agricultural practices during crop production can help maintain soil fertility and promote healthier crops that are better equipped to resist infestation.

4.3.2 Benefits of measures

The proposed measures, including improved management and pre- and post-harvest stages, will reduce aflatoxin contamination, thereby minimising aflatoxin exposure and aflatoxin-induced health cases. In turn, mortality and morbidity cases (for which economic values can be found) are avoided, alongside avoided economic productivity losses associated with illness.

4.3.3 Valuation basis

Various methods to monetising the impact of [avoided] aflatoxin-induced cases exist in the literature, including a top-down human capital approach that uses national-level economic statistics (Kirigia & Kubai, 2023), or bottom up approaches such as those that assess the value of prevented fatalities or treatment costs associated with specific aflatoxin-induced illnesses (e.g., liver-cancer) (Falade, 2022). There is no consensus on which approach is best overall; rather, different approaches work better in different circumstances. **For example, the cost of illness approach is considered more appropriate in developed countries where a large proportion of the estimate is the health care cost** (Meijer, 2018)**.**

In line with several peer-reviewed studies (Kirigia & Kubai, 2023) (Senkubuge F, 2021) (Kirigia & Mwabu, 2015), this assessment employs a human capital approach to convert the burden of disease from aflatoxin exposure into USD equivalents (using an economic proxy value based on national GDP and health expenditure), and incorporates an estimate of avoided productivity losses (indirect cost). The overall burden of disease is assessed using the disability-adjusted life year (DALY), a time-based measure that combines years of life lost due to premature mortality (YLLs) and years of life lost due to time lived in states of less than full health, or years of healthy life lost due to disability (YLDs). One DALY represents the loss of the equivalent of one year of full health. Using DALYs, the burden of diseases that cause premature death but little disability (such as HIV or tuberculosis) can be compared to that of diseases that do not cause death but do cause disability (such as cataract causing blindness).

This approach is adopted given that it's been widely used in peer-reviewed studies, is an accepted methodology (albeit not without its criticisms), and can be applied consistently across the seven countries with the data available[1].

The following formula is employed to estimate the economic value of DALYs lost/avoided from aflatoxin exposure into USD equivalents**:**

> *Economic value of avoided DALYs lost to aflatoxin exposure = % reduction in infestation * average number of DALYs lost from aflatoxin exposure * (GDP per person - current health expenditure per person)*

Additionally, productivity losses (indirect costs) associated with aflatoxin exposure is estimated using the following formula:

> *Economic value of avoided productivity losses = (GDP per person - current health expenditure per person) * % reduction in infestation * average number of DALYs lost from aflatoxin exposure * labour force participation rate minus the combined rate of unemployment and time-related underemployment.*

A detailed overview of input assumptions and data sources used in the valuation approach is presented in the accompanying Excel-based CBA; a summary of key input assumptions is offered below.

- **Beneficiaries of reduced infestation** are assumed to be the smallholder farmer population that adopts the proposed solutions. While it is possible that some of the agricultural produce travels to various national and potentially international markets, there is little evidence to understand the extent to which this occurs. Moreover, food safety standards in place domestically and in international markets are likely to limit the distribution and sale of contaminated crops beyond very local markets. Therefore, this

[1] An alternative approach - based on some studies in the literature - was considered (with a selection of potential input data points listed below), specifically assessing mortality and morbidity separately, and therefore requiring the two separate proxies of VSL (mortality) and VSLY (morbidity). YLD (number of years of healthy life lost due to disability per year) values were required to assess morbidity, however there is little data available for the countries of interest (and specifically for aflatoxins). In this regard, the approach considering mortality and morbidity together (using DALYs) and using economic proxy values based on GDP per capita and health expenditure is considered most suitable.

assessment makes the broad assumption that most of the contaminated agricultural produce is consumed locally and this is where most benefit would be felt.

- **Annual DALYs lost to aflatoxin exposure** are sourced from a report developed by the Partnership for Aflatoxin Control in Africa (Meijer, 2018). The reported DALY estimates are drawn from WHO data used for the global assessment of disease burden which showed that for all global sub-regions median rates for aflatoxin related DALY varied between 0.04 to 28 DALY per 100,000 population. Almost all countries report the burden of aflatoxin as premature mortality (YLL), and that the burden of aflatoxin lies in the group older than 5 years of age. Aflatoxin was considered an important hazard with a high disease burden in the sub-region AFR-D[2], which mostly encompasses West Africa. In that area, the median rates of aflatoxin related DALY per 100,000 population were 28 (7-78), while for sub-region AFR-E, this was 3 (1-8). In the absence of country-specific data on aflatoxin-related DALYs, the median value estimated for West Africa (28) has been applied to Burkina Faso, and the median value for AFR-E (3) has been applied to the other six countries, all of which fall into that WHO sub-region.
- **The reduction in DALYs lost to aflatoxin exposure resulting from the interventions** is based on an intervention-wide average. Assessing the extent to which infestation is reduced at each intervention type is difficult for the following key reasons: first, this would require understanding the share of DALYs across each intervention, data for which is unavailable; second, it is difficult to disaggregate between levels of adoption by beneficiaries (the literature suggest reduction rates for certain individual intervention types, but does offer evidence of the cumulative impact of deploying multiple interventions simultaneously); third the marginal gains from each individual intervention are expected to be minimal (this may be because if one intervention is implemented effectively (say at pre-harvest), the potential reduction capacity of other interventions later in the value chain are redundant); and fourth, available literature indicates that all interventions need to work together to effect change. Overall, given the lack of available evidence, this assessment makes the broad assumption that beneficiaries are adopting a range of interventions that, according to the literature (Catholic Relief Services, 2018) (Unnevehr, 2013) (Kumar Pradeep, 2017), cumulatively reduce infestation by ~85% on average.
- **For the relevant economic proxy values,** per capita GDP data was sourced from the International Monetary Fund (IMF) Database (IMF, n.d.), current health expenditure per person from the Global Health Expenditure Database of the World Health Organization (WHO) (WHO, n.d.), and adjusted labour force participation rate information from the World Bank (WHO, n.d.) and International Labour Organization (ILO, n.d.).
- **The health discount rate** used in the analysis is generally lower than the social discount rate used in other benefit calculations because health and life effects are expressed using welfare or utility values such as QALYs or DALYs rather than monetary values. The diminishing marginal utility associated with higher income does not apply as the welfare or utility associated with additional years of life does not decline as incomes rise. The health discount rate associated with low- and low-middle-income countries of 5% (Markus Haacker, 2020) is used. Higher and lower discount rates of 7% and 3% respectively are assessed in the sensitivity analysis.

4.3.4 Results

The resulting present values of the human health and productivity benefits associated with improvements in food safety resulting from the implementation of programme activities are shown in Table 4-2. The scenarios differ in terms of the discount rates applied (5% for base and best case; 10% for worst case) as well as estimates of the current prevalence of DALYs associated with aflatoxin exposure which are changed from 3 per 100,000 people in the base and worst case to 8 per 100,000 people in the best case for all countries other than Burkina Faso which is set at 28 per 100,000 across all scenarios.

Table 4-2: Health benefits (avoided DALYS and productivity losses associated with aflatoxin exposure), discounted

Country	Base	Worst case	Best case
Burkina Faso	0.97	1.29	1.09

[2] For the purposes of the Global Burden of Disease assessment, WHO stratified countries according to their relative levels of child and adult mortality. African countries fall into one of two strata: those with high child and adult mortality (AFR-D) and those with high child mortality and very high adult mortality (AFR-E).

Ethiopia	0.15	0.13	0.46
Kenya	0.20	0.18	0.69
Malawi	0.05	0.05	0.15
Tanzania	0.14	0.12	0.18
Uganda	0.10	0.09	0.30
Zambia	0.12	0.11	0.36

4.4 IMPACTS ON HOUSEHOLD INCOME

4.4.1 Context

The majority of today's poor in Sub-Saharan Africa rely on agriculture-related livelihoods as the primary source of income (Chegere M. J., 2018) and so interventions to reduce post-harvest losses and increase the quality of produce can contribute significantly to poverty reduction efforts. In developing countries, food loss has been estimated to reduce income by at least 15% for 470 million smallholder farmers and downstream value chain actors, most of whom are a part of the 1.2 billion people who are food insecure (The Rockerfeller Foundation, 2015). In the absence of the proposed interventions, the extent and impact of this lost income potential is likely to grow, given rapidly growing populations in target countries and the anticipated negative impacts of climate change on agricultural productivity.

4.4.2 Benefits of measures

The roll out of technical approaches for maintaining crop quality during harvesting, post-harvest handling and storage is expected to result in avoided post-harvest losses thereby increasing both the quantity of produce that farmers can sell and the price that can be obtained. This is expected to result in a subsequent positive impact on the levels of household income beneficiaries can obtain.

The impact pathway leading to changes in household income is as follows:

- **Reductions in food loss though FL-RS interventions increases the quantity of saleable produce and thus income,** expressed as the total amount of food loss avoided in tonnes multiplied by the market price for the crop.
- **Reductions in damage though FL-RS interventions improves the quality of produce and increases income,** expressed as a percentage price premium for quality which is applied to the standard market price.

Furthermore, studies of the impact of improved grain storage technologies on farmer welfare have consistently shown that farmers with access to improve storage technology tend to store crops for a longer period so that they can benefit from the higher prices during the lean season (Agarwal, Francis, & Robinson, 2018) (Omotilewa, Ricker-gilbert, Herbert, & Shively, 2018) (Gitonga, De Groote, Kassie, & Tefera, 2013). Studies have also shown that better post-harvest management and storage facilities also provide production incentives as they encourage farmers to invest and grow more crops (Kadjo, Ricker-Gilbert, Abdoulaye, Shively, & Baco, 2018), or adopt improved seeds (Omotilewa, Ricker-gilbert, Herbert, & Shively, 2018), which in turn my further reduce seasonality in food prices and consumption (Kaminski & Christiaensen, 2014).

4.4.3 Valuation basis

The total value of the increased household income resulting is presented directly in USD equivalent. It is calculated as the difference between the total income generated by all smallholder farmers with and without interventions. The following steps are employed to estimate the economic value of increased household income:

[1] *Income generated by farmers in the absence of interventions = total number of smallholder farmers * (quantity of crop produced (harvested) – quantity of crop lost) *market price of crop in USD*

[2] *Income from avoided food loss as a result of interventions = number of beneficiary farmers * tonnes of avoided food loss that is now marketable * market price of crop in USD * price uplift for improved quality (premium)*

[3] Income generated by non-beneficiaries with project in place = *number of smallholder farmers that do not benefit from interventions * (quantity of crop produced (harvested) – quantity of crop lost) *market price of crop in USD*

[4] *Income generated by beneficiaries with project in place = (number of beneficiary farmers * (quantity of crop produced (harvested) – quantity of crop lost) * percentage of crop that can fetch a premium * market price of crop in USD * price uplift for improved quality (premium)) + (number of beneficiary farmers * remainder of crop that doesn't fetch a premium * market price of crop in USD)*

[5] *Economic value of additional household income generated =* [4] + [3] + [2] – [1]

A detailed overview of input assumptions and data sources used in the valuation approach is presented in the accompanying excel-based CBA. A summary of key input assumptions is offered below.

- **There is limited systematic evidence of quality premiums paid to staple crop producers** (Chegere M. J., 2018). A review of the relevant literature revealed an estimate of the magnitude of changes in income (15%) amongst smallholder farmers and downstream value chain actors globally as a result of changes in the quality of produce (The Rockerfeller Foundation, 2015). Information from recently implemented large scale value chain development projects in Ethiopia suggest that farmers are able to attain quality-related price premiums in the order of 20-30%. Taking a conservative approach given data scarcity, a mark-up of 15% has been used as the price premium in the base case with a range between 10% (worst) and 25%-30% (best) depending on the country and crop type.
- **A price premium for quality is applied to both food loss avoided by households and the volume of produce that would have been marketed (at a lower price) in the absence of FL-RS.** It is anticipated that a proportion of baseline production is damaged to the point where it attracts a lower market price but is not lost altogether. FL-RS interventions may increase the quality of this produce and its associated market price and, as noted above, may also allow farmers to store crops for a longer period so that they can benefit from the higher prices during the lean season. While data on the proportion of baseline production that can be sold for a higher price is limited, it is assumed that FL-RS enable safety and quality enhancements or price arbitrage opportunities to between 30% and 80% of this production which can then be sold at a higher price. The proportion of existing production assumed to earn a premium varies by country and crop and is assumed to be lower for those crops that already command relatively higher prices.

4.4.4 Results

The resulting present values of the potential income gains to smallholder farmers associated with improvements in the quality of food crops available for sale on the market are shown in Table 4-3.

Table 4-3 - Present value of income gains from sale of higher quality output enabled by programme interventions (US$ millions)

Country	Base	Worst case	Best case
Burkina Faso	25.41	16.74	46.78
Ethiopia	26.16	12.88	45.93
Kenya	16.01	11.94	24.85
Malawi	13.85	9.28	22.72
Tanzania	15.49	12.04	21.32
Uganda	18.78	11.15	32.03
Zambia	11.89	8.37	21.57

4.5 GLOBAL CLIMATE REGULATION

4.5.1 Context

The agriculture and LULUCF sectors are the greatest contributors of emissions across all seven countries (Figure 4-2). The exception is Malawi, where the energy sector is reported the largest emitter in the Third National Communication (TNC), followed closely by the agriculture and LULUCF sectors (Figure 4-2). Global analyses indicate that on-farm activities and land use are the greatest contributors to emissions for commodities related to maize, rice, wheat, peas, soy and groundnut (Poore J, 2018). Farm activities account for up to 82% of emissions from rice, while land use contributes more than 45% of emissions from soybean. Food losses account for a significant proportion of emissions, particularly in smallholder value chains. 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.

The OECD-FAO Agricultural Outlook 2023–2032 highlights the necessity of raising crop production in Sub-Saharan Africa (SSA) over the coming decade to match the projected growth in demand. Projected estimates of changes in production, yields and harvested area for key commodity groups across SSA (OECD, 2023) have been used to calculate estimates for production of the crops in the target countries. Without intervention, emissions related to post-harvest losses on smallholder farms are expected to increase by between ~6% and ~17% across the target countries. This presents the minimum expected losses as climate change is likely to exacerbate these numbers, such as through changing rainfall regimes, increasing temperatures, and increases in the occurrence and severity of droughts and floods.

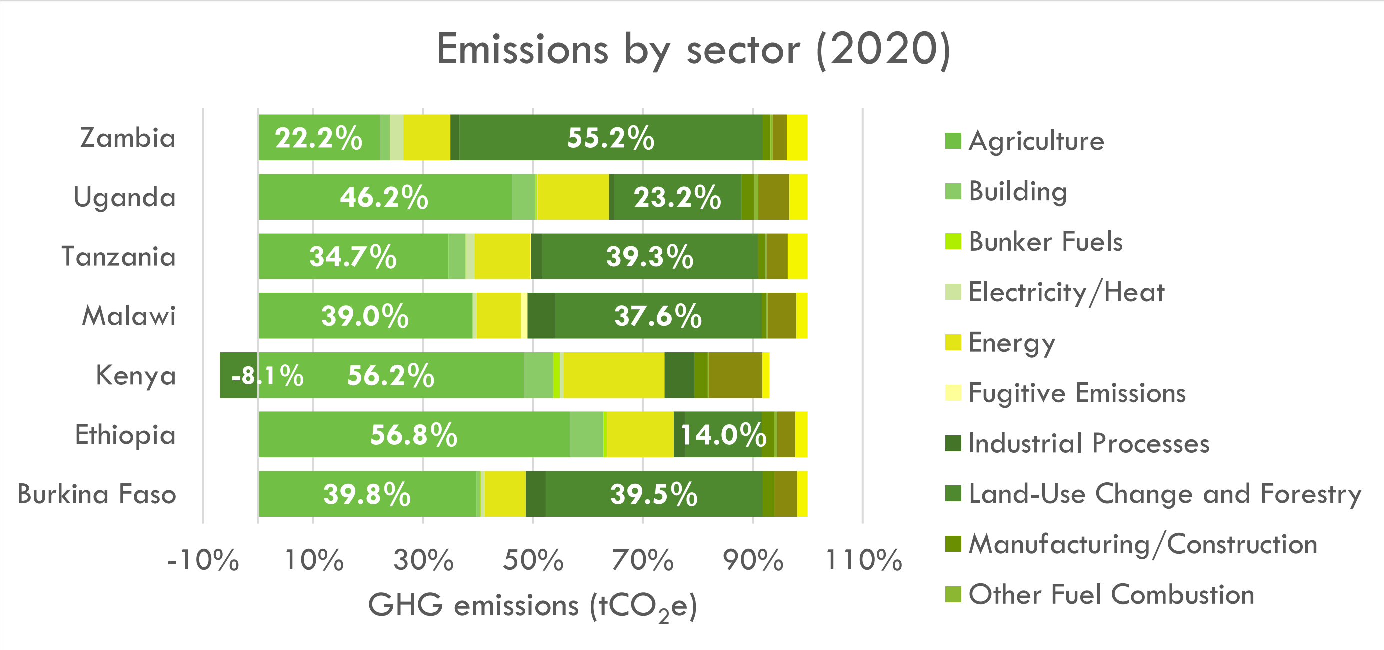


Figure 4-2 - Sectoral combined GHG emissions in 2020, highlighting the contributions of the agriculture and LULUCF sectors (Friedlingstein, 2023)

4.5.2 Benefits of measures

The proposed programme interventions are expected to contribute to a reduction in GHG emissions through avoided emissions associated with the crop production process, including energy used in farming, material inputs, fertilizer use, and energy used in handling, storage and processing.

4.5.3 Valuation basis

The net changes in GHG emissions have been estimated using information on:

- The cultivated areas, production and average yield of the different crops grown by smallholder farmers in each of the target countries, based on information from national annual agricultural surveys, census data, FAO data, the Global Data Lab and bespoke studies. Further information on the specific sources used for each country is documented in the Excel workbooks for both the mitigation models (Annex 22) and the economic analysis.
- The number of beneficiaries in each country
- The average food losses incurred at each stage of the value chain for each crop in each country at present (in the absence of intervention), based on data available from several sources, with highest priority given to data from the African Postharvest Losses Information System (APHLIS). Where APHILIS did not have data available on losses for a specific country, crop and value chain stage, the FAO Food Loss and Waste Database was the second priority data source. Where data were not available for a target country or crop, estimates from neighbouring countries were used. If any other estimate was used, these are specified per country/crop and documented in the Excel model.
- The effectiveness of different FL-RS at reducing food losses at each stage of the value chain based on a review of the available literature. These estimates, like each of those listed above, were extracted directly from the mitigation model (Annex 22). The savings per crop per year for each year of the assessment period were then calculated.

Using estimates of the typical losses associated with different crop types at each stage of the value chain, a possible total loss (%) of total production and amount in tonnes for the beneficiary farmers per commodity was calculated. 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 published in (Porter et al, 2016), and which have been used in several studies to estimate emissions, were then applied to derive estimates of the baseline annual emissions associated with the quantities of crops that would be lost in the absence of programme interventions. Estimates of the impacts of the proposed FL-RS at each stage of the value chain were then used to estimate the size of food loss and hence emissions reductions that could potentially be achieved through the programme interventions.

This yielded the estimates shown in Table 4-4 of avoided CO_2e emissions over the 10-year assessment period for each country.

Table 4-4 - Avoided emissions associated with programme interventions (Base and worst case scenarios)

Country	Total GHG emissions avoided as a result of food loss reductions in the value chain (tCO_2e)		
Burkina Faso	23,248.48		
Ethiopia	7,723.14		
Kenya	11,398.54		
Malawi	29,875.25		
Tanzania	28,985.51		
Uganda	7,761.20		
Zambia	52,199.11		
TOTAL	161,191.23		

The value of avoided emissions is calculated using the World Bank's recommended shadow price of carbon (SPC) for use in economic analysis (The World Bank, 2024)In line with the recommendations of the High-Level Commission on Carbon Prices, the guidance note recommends the use of a low and high estimate of the carbon price starting at US$40 and 80, respectively, in 2020 and increasing to US$50 and 100 by 2030. Given that the High-Level Commission report does not prescribe any specific carbon price values beyond 2030, the low and high values on carbon prices are extrapolated from 2030 to 2040 using the same growth rate of 2.25% per year that is implicit between the 2020 and 2030, leading to values of US$63 and $125 by 2040. The guidance note recommends the use of both the low and high price estimates in economic analyses because of the significant uncertainties arising from the unpredictability of future socio-economic and technological trends, as well as how mitigation costs are expected to be borne in different countries which depends on both the country context as well as willingness of the international community to transfer funds. The low price is used in the base case and best case scenarios and the high price in the worst case scenario.

Since the base year of the recommended SPCs is 2017, the prices have been adjusted to equivalent 2024 prices using the US Gross Domestic Product (GDP) deflator.

4.5.4 Results

The resulting present values of the avoided GHG emissions associated with crop production are shown in Table 4-5.

Table 4-5 Present value of carbon savings associated with programme interventions (US$ millions)

Country	Base	Worst case	Best case
Burkina Faso	1.66	0.84	2.21
Ethiopia	0.55	0.28	0.73
Kenya	0.63	0.40	0.89
Malawi	1.74	1.16	2.51
Tanzania	3.29	1.89	4.39
Uganda	1.05	0.60	1.59
Zambia	3.04	1.88	4.97

5 Cost-Benefit Analysis

5.1 CBA RESULTS

The estimates of costs and benefits associated with the proposed programme interventions in each of the countries have been profiled over a 10-year assessment period and then discounted using appropriate social discount rates (see Table 2-1 -). The benefits of the proposed interventions are estimated as the difference between the with- and without intervention scenarios.

The outcomes of the analysis at the programme level are shown in Table 5-1. This suggests that, under the current set of assumptions, the total package of interventions is cost-beneficial, with a NPV of US$69 million, a benefit cost ratio of 1.8 and an EIRR of around 56%.

Table 5-1 - Economic decision metrics for the programme (base case)

Total costs of interventions (US$ millions, undiscounted)	105
ENPV (US$ millions)	69
Benefit cost ratio	1.8
EIRR	56%

The most significant benefits, accounting for around 87% of total benefits, are associated with the income gains from farmers' ability to sell higher quantities of produce (as a result of reduced PHLs) and to obtain higher prices for their output as a result of both quality (and safety) improvements, and their ability to take advantage of inter-temporal price arbitrage opportunities due to improved crop protection and storage. Other important, but less significant, benefits are the value of avoided emissions (accounting for 7% of total benefits), food security (5% of total benefits), and health benefits (1% of total benefits). The relative contribution of each benefit stream is illustrated in the chart below.

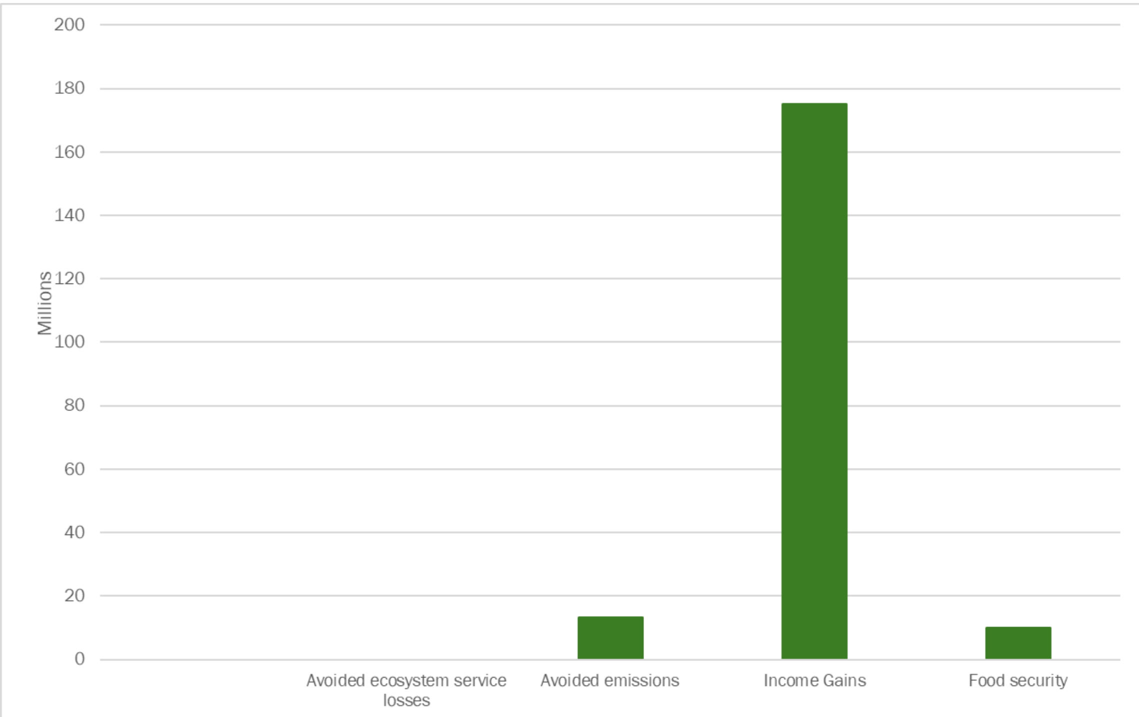


Figure 5-1 - Undiscounted value of benefits resulting from programme interventions

The results of the individual country-level assessments are shown in the table below.

Table 5-2 - Economic decision metrics for each country (base case, with replacement costs)

	Burkina Faso	Ethiopia	Kenya	Malawi	Tanzania	Uganda	Zambia
Total costs of interventions (US$, millions, undiscounted)	14.9	15.2	14.8	14.9	14.9	14.9	15.4
ENPV (US$, millions)	15.60	13.83	6.84	4.43	6.37	8.11	5.77
Benefit cost ratio	2.19	2.04	1.62	1.38	1.50	1.67	1.48
EIRR %	97%	81%	55%	37%	39%	55%	41%

The NPV, BCR and IRR presented here are considered conservative estimates given that:

- They **exclude a number of benefits that could not be consistently or reliably quantified and valued** for each of the seven countries with the available data. Missing benefits include the employment opportunities created through support provided to the establishment of MSMEs (particularly for the youth), and which in turn generate a number of other important economic benefits through, for example, reduced income volatility (which also strengthens household resilience to climate impacts and other external shocks), higher levels of household spending which increases demand for goods and services in the broader economy, and formal employment may allow households to spend more on education and health, which can augment human capital in the longer-term, adding to countries' long-term economic growth potential.
- The **values for some of the benefit streams are only partial estimates**. This is the case for the food security benefits where the values only consider impacts on human health and productivity. There are, however, benefits to livestock productivity from reducing the risk of aflatoxin-contaminated feedstocks.
- The **benefit estimates only consider the impacts associated with uptake of FL-RS by immediate (direct) beneficiaries** of physical interventions. They do not consider the effects of the awareness-raising and training activities that could stimulate uptake of solutions by the households that participate in those activities, and/or the spill-over effects to households that may not directly benefit from the programme but who may nevertheless decide that investments in FL-RS are worthwhile.
- The impacts of climate change on agricultural productivity and food loss have not been quantified in either the mitigation (carbon) or economic models. However, as noted in Section 4.1, climate change is likely to have a significant adverse effect on smallholder production (pre- and post-harvest) in the target countries in the absence of intervention. Moreover, higher food losses from exposure to damp, flooding and heat, will exacerbate forest loss and ecosystem degradation as farmers are forced to expand the area under production to meet growing demands on less productive land. **One would therefore expect both climate-related food losses and agricultural emissions in future years to be higher than those used in the models used to support this assessment**.

The main differences between the countries can be explained by:

- The types of crops included in the assessment. Some (e.g. rice) have substantially higher emissions factors than others such as wheat, teff and beans. As such, even considerable PHFL reductions have little mitigation impact in countries such as Ethiopia and Kenya. For example, the emission factor for wheat and beans respectively are 0.46 and 0.12 tCO_2e/tonne respective. For rice it Is 5.23, e.g. 43x more than beans and 11x more than wheat. Furthermore, some of the crops have substantially higher market value than others. For example, the average producer price per tonne of cow peas in Burkina Faso is more than double that for maize in other countries. Similarly, the crops also have substantially different prices associated with them, varying between US$185 per tonne for maize in Zambia to US$1,119 per tonne for beans in Kenya.
- The prevalence of aflatoxin-related illnesses and hence DALYs in different regions. The number of aflatoxin-related DALY's in Burkina Faso is over nine times that of countries in Eastern and Southern Africa. Therefore, interventions to reduce crop infestation in Burkina Faso, will have a relatively larger effect.

5.2 SENSITIVITY ANALYSIS

Sensitivity analysis has been conducted to examine the extent to which changes in key underlying assumptions (i.e. where the greatest uncertainties lie) affect the outcomes of the economic assessment. In particular, the effects of changes in the following variables have been used to define 'worst case' and 'best case' scenarios which are intended to reflect the lower and upper endpoints of the range within which the actual value of benefits is expected to lie:

- The social discount rate
- The food loss reduction rates associated with different types of solutions at different stages of the value chain for each crop type
- The price premiums that farmers may earn on the higher quality outputs that implementation of FLR-RS enables
- How land use is expected to change in future in the absence of interventions, particularly with respect to rates of deforestation and forest degradation
- The shadow price of carbon

The results of the sensitivity analysis are shown in the table below.

Table 5-3 - Economic metrics under a 'worst case' scenario

	Burkina Faso	Ethiopia	Kenya	Malawi	Tanzania	Uganda	Zambia	Programme
Total costs of interventions (US$, millions, undiscounted)	14.9	15.2	14.8	14.9	14.9	14.9	15.4	105
ENPV (US$, millions)	8.6	2.7	2.3	-0.6	0.8	1.0	0.3	17.7
Benefit cost ratio	1.8	1.2	1.2	0.9	1.1	1.1	1.0	1.03
EIRR %	69%	28%	26.79%	6%	14%	18%	12%	12%

- Economic metrics under a 'best case' scenario

	Burkina Faso	Ethiopia	Kenya	Malawi	Tanzania	Uganda	Zambia	Programme
Total costs of interventions (US$, millions, undiscounted)	14.9	15.2	14.8	14.9	14.9	14.9	15.4	105
ENPV (US$, millions)	37.6	35.5	16.2	14.6	15.3	21.4	17.4	165
Benefit cost ratio	0.0	3.7	2.4	2.2	2.2	2.6	2.3	2.80
EIRR %	445%	398%	131%	107%	96%	145%	100%	165%

The results suggest that, even under a worst case scenario, which employs the most conservative assumptions regarding the value of the benefits and the highest discount rate, the programme as a whole, is cost-beneficial.

5.3 CAVEATS AND LIMITATIONS

The CBA is necessarily high-level and is therefore subject to a number of caveats and limitations, as follows:

- As noted earlier, it is likely to significantly under-estimate the total value of benefits. This is because some important benefits are omitted from the quantitative analysis either because the data necessary to reliably quantify and value the benefits was not available, or because the effort required to derive estimates was considered disproportionate to the scale of benefits at stake. Partial or missing benefits include the impacts of programme interventions on employment creation, the impacts of aflatoxin-contaminated crops on livestock and, at the household level, the cost savings accruing to farmers for inputs such as pesticides, fertilizers, and water applied to crops that would otherwise be spoilt or lost post-harvest.

- Importantly, the model does not consider the wider economic benefits that FL-RS would enable including through value chain expansion, economic diversification, as well as food system and market transformation.
- The economic assessment is based on national and regional datasets which may not accurately reflect the situation on the ground amongst the target households and communities. A more detailed and nuanced understanding of prevalence of malnutrition, under-nourishment, access to markets, etc will be needed at the detailed planning and design stage.
- Related to the above, the spread of countries and absence of consistent and comparable datasets across the countries necessitated use of proxies and assumptions, particularly regarding how the situation might evolve in future in the absence of the programme (given uncertainties in climate, demographic and technological change, and the effects and influences of policy and other measures) which means that there is also a high level of uncertainty in the resulting estimates. These uncertainties have been accounted for as far as possible through the sensitivity analyses and the specification of the likely range within which the actual economic performance of the programme is expected to lie.

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APPENDIX A Economic Model

See accompanying Excel file.