

The Rockefeller Foundation

Reducing Food Loss Along African Agricultural Value Chains for Social, Environmental and Economic Impact

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THE
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Monitor **Deloitte**.

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List of Acronyms and Abbreviations

FAO	Food and Agriculture Organization
MNC	Multinational Corporation
MPU	Mobile Processing Unit
PHL	Post-harvest Loss
PPD	Post-harvest Physiological Deterioration
RDA	Recommended Daily Allowance
ROI	Return on Investment
SHF	Smallholder Farmer
SPV	Special Purpose Vehicle
SSA	Sub-Saharan Africa

Table of Contents

Executive Summary	4
1. Setting the Context: Food Loss from Smallholder Farmer to End-Market Buyer.....	5
1.1. Food Loss and its Impact on Undernourishment and the Triple Bottom Line	5
1.2. Insufficient Focus on Reducing PHLs.....	5
1.3. Definitional Clarification: Food Loss vs. Food Waste	6
1.4. PHL by Crop Type	7
2. Impact of PHL Interventions: Economic, Health, and the Environment	8
2.1. Economic Impact	8
2.2. Health Impact.....	8
2.3. Environmental Impact.....	9
3. Evaluation of PHL Solutions through ROI Analysis.....	10
3.1. Taxonomy of Available PHL Solutions	10
3.1.1. Product Solutions	10
3.1.2. Process Solutions	10
3.2. Estimating the Return on Investment (ROI)	11
3.2.1. Estimating a PHL Solution's 'Return'	12
3.2.2. Estimating a Solution's Cost	14
3.3. ROI Analysis Outputs	15
4. Considerations for Implementation of PHL Reduction Solutions	17
4.1. Interventions to Reduce PHL.....	17
4.1.1. Product Interventions	17
4.1.2. Process Interventions	18
4.1.3. Producer Interventions.....	19
4.1.4. Processing and Payments Interventions	19
4.2. Systemic Nature of Post-Harvest Losses & Implication for Implementation of PHL Interventions	20
5. Models for PHL Reduction Intervention	22
5.1. Contracted Fruit and Vegetables Model	22
5.2. Processed Food Crops Model	23
5.3. Improving Grain Availability	24
6. Conclusion and Guiding Principles.....	25

Foreword

The Rockefeller Foundation's history in agriculture and Africa is vast; from supporting the spark of the Green Revolution in Asia and Latin America to foundational support to the International Institute for Tropical Agriculture, our commitment has not wavered throughout our century old global mission. Though the targets of our agriculture work have changed vastly over time, our agriculture goals have remained constant. Through the Foundation's dual goals of Inclusive Economies and Building Resilience, we have worked via several of our initiatives to increase food productivity, secure food supplies, enhance farmer profit and build stronger, more resilient communities.

A majority of Africans depend on agriculture for their livelihoods, yet millions of African farmers and their families are trapped in poverty. With Africa's growing population, it is critical that small scale farmers have the means to make the transition to commercial production, both to improve their own livelihoods and also to help ensure a food supply that meets the needs of the continent.

Globally, food production will continue to be affected by two driving forces: the increase in population, particularly in Africa and; climate change, which will make the challenge of feeding many more people much greater.

To meet these two challenges, we must increase food security, and do it sustainably. Several measures have been suggested: halting farmland expansion, closing yield gaps on underperforming land, increasing cropping efficiency, shifting diets, and reducing post-harvest loss.

The Rockefeller Foundation is working to transform African agriculture from a development problem to an economic opportunity. One way is through focusing on that last measure, which the Foundation has identified as an area for greater exploration using our resources and expertise.

This is not just about feeding more people; it is about protecting and helping producers, and ensuring that the resources for growing food are used effectively. To that end, there is a tremendous opportunity to halt food losses, which adversely affect the livelihoods of smallholder farmers by decreasing the amount of harvest they can sell.

The Rockefeller Foundation, provided a grant to the private company Monitor Deloitte to conduct a return on investment analysis on established and emerging post-harvest loss solutions to identify potential areas of investment. Despite the promising potential of the technologies on reducing loss, the analysis shows that no "silver bullet" exists and interventions at a single point in the value chain tend to fail.

To reduce post-harvest losses, actors need to align and an integrated set of activities is required to achieve impact across the value chain e.g. ensuring access to loss reducing technologies; linking smallholder farmers to consistent market demand; access to finance to invest in technologies and; ensuring farmers have the appropriate training.

Through our efforts at scale, we envision contributing to a systemic change through which millions of rural agricultural dependent people's lives are improved, their socio-economic resilience is increased and their food and nutritional security is enhanced through efforts to mitigate post-harvest loss in food crop supply chains.

Executive Summary

The amount of food lost each year due to post-harvest loss (PHL) is enough to feed the total number of undernourished people globally. In sub-Saharan Africa (SSA) alone, which unfortunately is home to over 230 million people suffering from chronic undernourishment, 30-50% of production is lost at various points along the value chain. Efforts to reduce PHL thus provide an attractive opportunity to improve food security across the globe, but especially in SSA. A range of solutions exist that address PHL, but there is not a clear consensus for which are best at effectively reducing losses. Perhaps in this case “best” should be defined by clear quantifiable evidence to help guide decision-making. It is this motivating premise that underpins the work described in this report.

Section 1 provides an introduction to the challenge that PHL poses, and explains that emphasis is too often placed on increasing production levels or yields and not enough on reducing PHL. However, it also explains that while reducing PHL directly increases available food, it also drives secondary benefits in terms of economic, health, and environmental impacts. The section concludes by offering a clarifying distinction between food loss and food waste and offering data on which crop types experience the greatest degrees of loss in SSA.

Section 2 provides a deeper assessment of the secondary benefits of reducing PHL. It explains that with reduced PHL, smallholder farmers (SHFs) have more crops available to sell, thereby generating increased income. Similarly, greater quantities of nutritious fruits and vegetables can reach the market, and fewer spoiled and toxic staples are likely to be consumed. With increased crop volumes hitting the market – and without an increased drain on valuable inputs like arable land and water – less pressure is put on the environment to make additional food available to consumers.

Section 3 introduces a variety of solutions to reduce PHL, and provides a taxonomy for describing these. It outlines a methodology that was used to evaluate these solutions in an attempt to rank the solutions that most effectively reduce losses and deliver on the secondary benefits described above. In an attempt to be objective and quantitative, a Return on Investment (ROI) analysis was conducted; the section describes the results of this assessment.

Section 4 offers some considerations for implementing PHL solutions, and argues that solutions are most effective when implemented in combination and not in isolation. PHL occurs at various points along the agricultural value chain – from processing to storage to distribution. As such, solutions should be combined to span the entire value chain to effectively address the problem.

Section 5 describes three models for PHL reduction intervention that combine various high-ROI solutions. Selecting which model is most effective depends on the crop varieties considered as certain models are more applicable than others.

Section 6 concludes that the challenge of reducing PHL is not insurmountable, but that collaboration will be required by various actors across the entire agricultural ecosystem. It hypothesizes that the problem will be addressed most sustainably when multiple actors are mobilized by market-driven motivations.

1. Setting the Context: Food Loss from Smallholder Farmer to End-Market Buyer

1.1. Food Loss and its Impact on Undernourishment and the Triple Bottom Line

Reducing post-harvest losses (PHL) can play a pivotal role in eradicating extreme hunger and feeding a growing global population. Over 870 million people suffer from chronic undernourishment, 27% of which are in Africa alone.¹ This challenge is exacerbated by a growing global population, particularly in Africa where its population is expected to grow by 2.5% (1990 to 2020) compared to a global average of 1.1%.²

While increasing agricultural productivity in Africa may serve to alleviate this pressure, PHL reduction is necessary to ensure that additional production is consumed rather than lost. Similar to filling water in a bucket riddled with holes – where only a portion of the filled quantity makes it to the intended destination – gains made by increased production must be complemented with sufficient reduction in PHL. Today, the primary problem facing smallholder farmers in sub-Saharan Africa (SSA) may not be insufficient production levels. Annually, approximately 32% of crops produced (or 1.3 billion tons) and 24% of calories produced (or 1.5 quadrillion kilocalories) are not consumed; this represents enough food to feed approximately 1.6 billion people.³ The impact of reducing PHL can be seen in the context of a triple bottom line, whereby a reduction in PHL has an economic, social, and environmental impact. Economic in that increased sales from crops harvested drives up farmer incomes; social in that increased sales from crops harvested allows for increased planting diversification thus increasing the availability of more nutritious food and thereby improving health; and environmental in that valuable resources (e.g., arable land, water, etc.) are not wasted on crops that are never consumed. It is this broad and compound effect of PHL that makes reducing it an attractive opportunity to improve the well-being of humanity.

1.2. Insufficient Focus on Reducing PHLs

Increases in available food is primarily driven by three types of interventions: (i) increasing the area of land cultivated, (ii) increasing yields on existing cultivated land and (iii) reducing PHL.

The majority of efforts have primarily been focused on increasing yields, and for good reason – yields in Africa (1.1 tons per hectare) were approximately one-third of the global average (3.2 tons per hectare) between 2008 and 2010.⁴ Efforts to improve yields are preferable to efforts to increase the area of land cultivated since an increase in yields represents an improvement in efficiency and less of a drain on resources, particularly land.

¹ World Hunger Education Service, 2013, 'World Hunger and Poverty Facts and Statistics'. Available at: <http://www.worldhunger.org/articles/Learn/world%20hunger%20facts%202002.htm>

² United Nations Department of Economic and Social Affairs: Population and Development Database. Available at: <http://www.un.org/en/development/desa/population/publications/development/population-development-database-2014.shtml>

³ This is based on an assumed daily caloric intake of 2,500 per person and total food wasted of 1.5 quadrillion kilocalories

⁴ Fuglie & Rada, 2013, 'Resources, Policies and Agriculture Productivity in Sub-Saharan Africa'. Available at: <http://www.ers.usda.gov/media/1037838/err145.pdf>

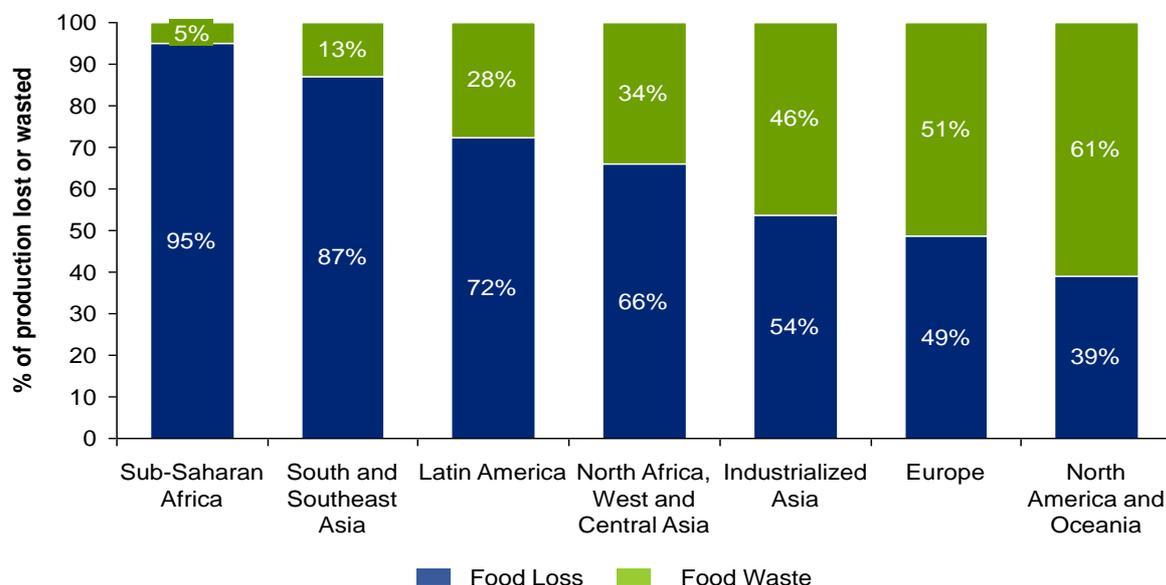
At the same time, however, efforts should be intensified to reduce PHL so that more of the food produced actually makes it to consumers, for the same level of inputs. This will help to ensure that envisaged improvements in crop production (via improved yields) have the desired impact on food availability for growing SSA populations. While increasing crop production has, and continues to, receive great attention, disproportionately fewer resources have been employed to address the related and equally challenging issue of PHL.

It is encouraging to note that efforts to address PHL have been implemented by some market actors. However, many technologies and interventions have not performed well due to weak innovation delivery systems, user perceptions, poor adaptability to socio-cultural and economic contexts, and in cases where interventions are adopted, lack of the necessary support to ensure intervention improvement and correct usage. As such, further investment and focus is required to develop and implement holistic approaches for loss mitigation.

1.3. Definitional Clarification: Food Loss vs. Food Waste

It is important to distinguish between food loss and food waste. PHL occurs along the value chain from harvest through to the point at which food is made available to consumers, whereas food waste refers to food that is wasted by consumers themselves.⁵ While more developed countries grapple with the largest proportions of food waste, developing regions such as SSA face higher proportions of food losses. As Figure 1 indicates, approximately 95% of losses in SSA occur before the consumer buys the crop, while over half of losses in Europe and North America occur after the crop has reached the consumer. Thus, optimization of supply chains between smallholder farmers (SHFs), in particular, and the consumer is key to reducing losses in SSA.

Figure 1: Food Loss vs Food Waste by Region



Source: 'Reducing Food Loss and Waste', World Resources Institute

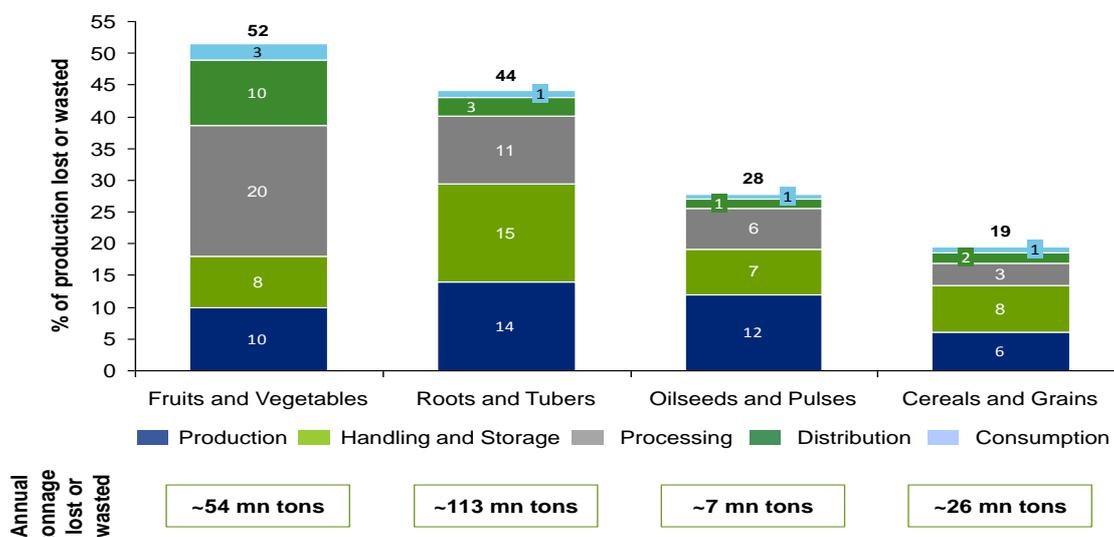
⁵ Losses are also defined by intention – that is, when a crop is produced for human consumption, but is used for other purposes (e.g. animal feed, fertilizer, glue)

The effect of food losses in SSA is compounded by the fact that the vast majority of the population relies on agriculture as a source of income – over 80% in some countries.⁶ Therefore, losses have far reaching consequences, including farmers’ inability to feed themselves and their families and an inability to pay for basic household expenses as a direct result of insufficient incomes.

1.4. PHL by Crop Type

The challenge of PHL in SSA is varied and complex. Some of this complexity is evident in the variation in losses that occur at different stages of the value chain and how PHL differs by crop type. These variations are illustrated in Figure 2 below.⁷ Fruits and vegetables incur the greatest percentage loss (approximately 52% of production, or 54 million tons per annum).⁸ These losses primarily occur further up the value chain during processing and distribution. During processing, losses often occur as a result of discarding edible parts of the fruit or vegetable not suitable for processing. During distribution, losses are typically caused by mechanical damage (e.g. bruising) during transportation. Roots and tubers (e.g. cassava) on the other hand incur the highest volumes of loss (in terms of absolute production lost). This loss predominantly occurs soon after harvest due to the high levels of perishability associated with these crop types. Cassava, for example, can perish within 48 hours of harvesting due to post-harvest physiological deterioration (PPD). While losses are not as high for cereals, PHL also typically occurs soon after harvest, particularly during handling and storing. Inadequate storage often allows moisture to build, thus attracting pests and reducing the amount of edible crop available for consumption.

Figure 2: Food Loss by Crop in SSA



Source: 'Global Food Losses and Food Waste', FAO; FAOSTAT

PHL is an issue that affects all crops at multiple stages of the value chain between production and consumption. Large opportunities for PHL reduction exist along the entire value chain, however high impact solutions will be required to affect *several* crop types at *more than one stage* of the value chain

⁶ World Bank, Employment in Agriculture, Available at: <http://data.worldbank.org/indicator/SL.AGR.EMPL.ZS>

⁷ Loss percentage figures are adjusted to reflect losses as a percentage of agricultural production rather than as a percentage of the tonnages that reach each stage of the value chain

⁸Gustavson, J. and Sonesson, U., 2011 'Global Food Losses and Food Waste'. Food and Agriculture Organisation. Available at: <http://www.fao.org/docrep/014/mb060e/mb060e.pdf>

2. Impact of PHL Interventions: Economic, Health, and the Environment

PHL interventions can have broad economic, health, and environmental impacts. While a PHL intervention will have the primary result of reducing losses, it may also create important secondary impacts; for example, it could improve the livelihoods of farmers and other value chain actors, or provide an opportunity for nutritional security and production diversity, or improve the use of natural resources and stewardship of the broader environment.

2.1. Economic Impact

PHL interventions contribute to two broad economic impacts. Firstly, they contribute to income creation and economic development. Secondly, they help ensure that returns are maximized on the investments that SHFs make in agricultural inputs (e.g. fertilizer, improved seed, crop protection products, etc.).

Many households are dependent on agriculture as their primary, and often only, source of income. The sector employs over 75% of the population in many SSA countries, over three quarters of whom are SHFs. For instance, in East Africa alone, 80% of the agricultural workforce are SHFs.⁹ These SHFs are typically economically vulnerable due to unpredictable and inconsistent incomes caused by, for example, reliance on rain fed agriculture, lack of training on proper farmer methods, and lack of access to finance to purchase agricultural inputs and other factors for production. Thus the importance of PHL interventions on smallholder farmers cannot be overstated. Reducing PHLs not only address food security issues, but also drive up income that can be used towards other important household expenses, such as education, health, agricultural inputs, etc.

In addition, PHL interventions ensure that returns are maximized on the production investments that SHFs make. Significant costs are incurred by farmers and other actors in producing crops. These include costs of agricultural inputs (e.g. fertilizer, crop protection products, irrigation, etc.), investments into infrastructure and equipment, and capacity building and training. For example, in Zambia the average cost to produce a 50 kg bag of maize was just over \$10 for a SHF in 2010, which included input costs, labor costs and land rental costs.¹⁰ A loss of crops along the value chain drives down the return that farmers and other actors capture on these types of investments.

2.2. Health Impact

PHL interventions also have important health implications. They both improve the quantity and quality of relatively nutritious crops sold, and they reduce toxins that reach the market from spoiled and infested crops.

Perishable fruits and vegetables are a relatively important source of nutrients, and as noted above in Figure 2, experience the highest percentage of crop losses and waste. Unfortunately, they are often excluded from traditional PHL interventions, which typically focus on staples. Reducing PHLs, particularly in fruits and vegetables, improves nutritional security by ensuring greater volumes and variations of healthy crops make it to the market.

⁹ Salami A., Kamara A. and Brixiova, Z., 2010, 'Smallholder Agriculture in East Africa: Trends, Constraints and Opportunities'. African Development Bank. Available at: <http://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/WORKING%20105%20%20PDF%20d.pdf>

¹⁰ Burke, W., Hichaambwa, M., Dingiswayo, B. and Jayne, T.S., 2011, 'Food Security Research Project'. Food Security Research Project Working Paper No. 50. Available at: <http://fsg.afre.msu.edu/zambia/wp50.pdf>

PHL interventions can also reduce the quantity of toxins that hit the market, particularly aflatoxins, which can contaminate grains that have been poorly stored. The Food and Agriculture Organization (FAO) estimates that a quarter of food crops are contaminated with aflatoxins annually.¹¹ Thus there are important widespread benefits associated with such interventions. Aflatoxins have been found to be associated with a range of illnesses including liver cancer and cirrhosis, growth retardation and susceptibility to malaria and HIV/AIDS.¹² Furthermore, it is not uncommon for aflatoxin contamination to cause fatalities. For example, more than 150 deaths were reporting in Kenyan between 2004 and 2005 due to consumers eating contaminated maize.¹³

2.3. Environmental Impact

The global environmental footprint of wasted resources is significant; as such, reducing PHL can have significant impact on relieving pressure on the environment. The FAO estimated that the carbon footprint of wasted food globally is 3.3 Gigatonnes of CO₂ equivalent. If PHL were a country, this would rank it as the third top emitter after the US and China.¹⁴

A reduction in PHL means that there is less need to convert more land to farmland because production volumes actually make it to market and thus fulfill demand, reducing the burden on deforestation and offsetting the carbon footprint of crops grown. The potential impact is immense, with wasted food currently occupying almost 1.4 billion hectares of land, which is close to 30% of the earth's agricultural area.¹⁵

A reduction in PHL would also result in more efficient use of water, reducing the need to withdraw water from aquifers. Currently the blue water loss footprint is an estimated 250 km³, three times the volume of Lake Geneva.¹⁶

¹¹ Partnership for Aflatoxin Control in Africa, 2013, 'PACA Strategy 2013-2022, Available at: <http://www.aflatoxinpartnership.org/uploads/PACA%20Strategy%202013-2022-%20FINAL%20formatted%20for%20A4.pdf>

¹² Ibid

¹³ International Food Policy Research Institute, 2010, 'Aflatoxins in Kenya: An Overview'. Available at: <http://www.ifpri.org/sites/default/files/publications/aflacontrolpn01.pdf>

¹⁴ Food and Agriculture Organisation, 2013, 'Food Wastage Footprint: Impacts on Natural Resources'. Available at: <http://www.fao.org/docrep/018/i3347e/i3347e.pdf>

¹⁵ Ibid

¹⁶ Ibid

3. Evaluation of PHL Solutions through ROI Analysis

3.1. Taxonomy of Available PHL Solutions

Numerous solutions can be employed to reduce PHL and create desired secondary impacts. These solutions can be broadly categorised as *product solutions* (i.e. technologies – which can be further broken down into storage and handling technologies and value addition technologies) or *process solutions* (i.e. procurement channels).

3.1.1. Product Solutions

Storage and handling solutions refer to those technologies that improve conditions at the storage and handling stage of the value chain and are primarily focused on reducing losses – examples may include hermetic bags or metal silos that allow SHFs to reduce losses by limiting crop exposure to moisture, heat and pest infestation. This allows them to store crops for longer, enabling them to better navigate price troughs and to receive a price premium for higher quality crops. Other product solutions at the storage and handling stage of the value chain help improve the shelf life of relatively nutritious fruits and vegetables; for example, Gum Arabic Coating, an edible extract from certain species of acacia trees, can be applied in an aqueous solution to fruits and vegetables to increase their shelf life.

Other product solutions are primarily focused on value addition (these could also be defined as processing solutions), but also have the effect of decreasing perishability and, thereby reducing PHL. These solutions include mobile processing units (MPUs), solar dryers and graters & pressers. They typically reduce PHL by limiting the handling and transportation of raw crops (if they are employed on or near-farm) and by increasing shelf life.

3.1.2. Process Solutions

Procurement channels are not necessarily designed to reduce PHL; however their successful implementation allows for the efficient transfer of crops from producers and agro-processors to consumers. This means that crops are less likely to perish while farmers wait for a buyer and, hence, is a critical step in ensuring crops achieve their intended use.

Over 60 solutions were identified for assessment. These solutions then went through an initial filtering process, which investigated measurability (i.e. whether its impact could be quantified), scalability (i.e. whether the impact could be sustainably scaled), replicability (i.e. whether the solution could be used for several crops in a number of geographies) and ease of implementation (i.e. whether the solution is feasible and practical). 18 leading solutions remained after this filtering process. Table 1 below describes these solutions.

Table 1: 18 Solutions Assessed by ROI Analysis

		PHL Solution	Solution Description
Product Solutions	Storage and Handling Solutions	Super Grain Bags	Multi-layered, water resistant, polyethylene storage bags used for grain storage
		Gum Arabic Coating	Edible coating manufactured from acacia tree sap used to coat certain fruits and vegetables to delay ripening
		ZeroFly Bags	Insecticide-incorporated storage bags for crops capable of preventing pest infestations
		Liquid Air Refrigeration: Cold Storage	Cooling of air to very low temperatures for cold storage and transport of perishables; technology still to be piloted in an African context
		Warehouse Receipts System	Secure storage combined with deposit system and credit mechanism; difficult to implement in contexts where financial systems are not mature
		Heavy Moulded Plastic Containers	Durable, protective, and cost effective plastic containers with the ability to prevent crop damage during storage and transportation
		Metal Silos	Robust, water resistant, hermetic storage units constructed from galvanized iron, usually used for aggregation and storage of grains
		Plastic Silos	Storage units made from food-grade, UV-resistant flexible PVC for both indoor and outdoor use; cheaper and less durable than metal silos
		Low Energy Cooling	Micro controller that allows conventional window air conditioning units to operate at colder temperatures at lower costs for cold storage
	Value Addition Solutions	Mobile Processing Units	Autonomous Mobile Processing Units used, for example, to transform cassava root into high-quality cassava cake or thresh maize
		Graters and Pressers	Traditional means of transforming crops from raw state into one with a longer shelf life; used particularly for cassava
		Liquid Air Refrigeration: Individual Quick Freezing	Process whereby individual crops are frozen using liquid air thereby extending shelf life and preserving nutritional integrity
		Mobile / Solar Drying	Diesel-powered or solar driers used to reduce moisture in crops, thereby extending shelf life allowing SHFs to sell crops at higher prices
		Growtainers	'Mobile farms' built inside insulated containers modified to provide a controlled environment for growing agricultural products hydroponically
Process Solutions	Procurement Channels	Collection Centres	Aggregation points that link farmers to buyers, primarily offering grading, packing and storage services
		Contract Farming	Contractual agreement where a primary off-taker provides a farmer with agricultural inputs and training to produce contractually specified crops
		Direct Sourcing	Procurement channel where farmers establish contractual agreements directly with buyers; limited inputs and technical assistance provided
		Supply Chain Technology Platforms	Use of technology platforms to connect farmers and potential buyers, e.g. AgriManagr

Source: Monitor Deloitte Analysis

3.2. Estimating the Return on Investment (ROI)

These 18 solutions were then assessed based on their relative return on investment (ROI). The primary intention of the ROI analysis was to provide insight into which solutions are most likely to drive the highest impact for a given cost. The analysis sought to answer questions such as –

- (i) For a given level of spending, which solution(s) will result in the greatest reduction of tons wasted?
- (ii) For a given level of spending, which solution(s) will create the greatest impact across the three focus areas that make up the triple bottom line (economic, health, and environmental)?
- (iii) For a given level of spending, which solution(s) will create the greatest impact on one particular focus area that forms part of the triple bottom line?

The section below outlines how the return was defined and calculated and the subsequent section details how the costs / investments were estimated.

3.2.1. Estimating a PHL Solution's 'Return'

In this context, the 'return' is not a monetary figure, but rather a measure of the effectiveness of a particular solution. The metric used to measure this effectiveness in the ROI analysis is important given the multi-faceted potential impact of different solutions and the need to compare the 18 solutions on an objective basis. In particular, ROI metrics were assessed:

- Tons Wasted ROI: Captures the broad impact of a solution using one universal measure of PHL (i.e. tons of PHL reduced).
- Impact ROI: Assesses the solutions based on their impact on a range of factors related to the triple bottom line (i.e. economic, social and environmental).

Below, more detail is provided on how these metrics were calculated.¹⁷

Metric: Tons Wasted

Measuring tons of waste is widely used as an indicator for measuring post-harvest losses. The indicator speaks directly to a key area of concern – the amount of food available and lost. It is also relatively easy to quantify and universally accepted as a measure of production.

However, looking only at the weight of crops lost may result in a bias towards relatively heavy crops (e.g. cassava), which does not necessarily correlate with impact. One unit of a relatively heavy crop may actually have a lower impact on incomes, health and the ecosystem than a unit of a relatively light crop. By way of illustration, 100g of maize provides only 4% of the recommended daily allowance (RDA) of vitamin A, whereas 100g of tomato provides 16% of the RDA of vitamin A. Hence, if comparing a solution that would reduce PHL of maize by 100 tons versus another solution that would reduce PHL of tomato by 50 tons, using tons wasted as a metric would lead to prioritization of the maize PHL solution. However, from a nutritional perspective the tomato PHL solution should be prioritized.¹⁸ This potential bias was corrected by assessing the impact ROI (discussed further below), which allows for direct impact on factors such as nutrition to be estimated.

Other universal measures of PHL were also considered as potential alternatives to tons wasted.¹⁹ However, tons wasted provides the most objective basis for comparing solutions (as long as biases are corrected with the impact assessment), and hence, this metric is used in the ROI analysis.

Metric: Impact on the Triple Bottom Line

While the tons wasted ROI allows for objective comparison of the solutions, a great deal of insight can also be drawn by measuring each solution's impact on the triple bottom line. These areas are: secure livelihoods (e.g. income), revalue ecosystems (e.g. more efficient usage of environmental resources), and advance health (e.g. improved nutrition).

¹⁷ The following considerations should also be taken into account when analyzing a solution's impact: (1) Only the immediate impact of a solution is considered. In other words, the second-round effect of a particular solution is not considered. For example, if a solution improves a farmer's income, the approach would not consider that this may allow the farmer to purchase more seed to produce more and further increase his income; (2) The estimation of a solution's impact is typically based on a specific example (or set of specific examples). While this is representative of the impact the solution would have more generally, it does not provide context specific impacts

¹⁸ Nutrition Data, 2014, 'Nutrition Facts: Tomato'. Available at: <http://nutritiondata.self.com/facts/vegetables-and-vegetable-products/2682/2>

¹⁹ Firstly, monetary value was considered since reducing losses of higher value (rather than heavier) crops may be more indicative of a solution's effectiveness. Most obviously, this may be because higher value crops are larger income generators, but also because value may be associated with other beneficial factors such as nutrition. However, given the inherent difficulties of measuring crop value (due to, for example, volatile and context-specific prices) as well as the fact that economic value is not necessarily the focus of the analysis, this metric was not used.

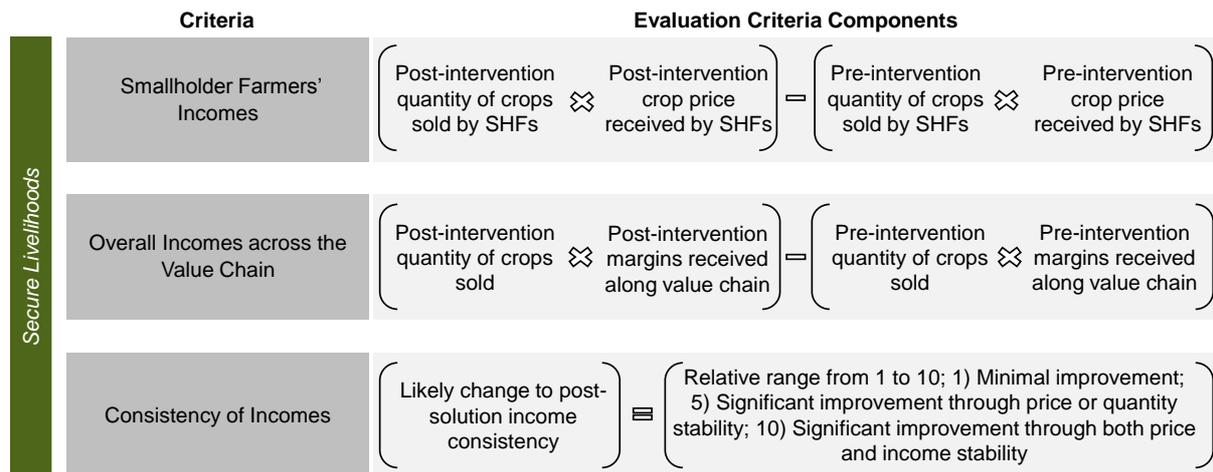
Secondly, caloric value is a widely available measure that also speaks directly to the issue of eradicating hunger. However, caloric value does not necessarily capture the nutritional content of crops and, hence, does not go further than tons wasted in terms of assessing the impact on nutritional security. Moreover, this measure may significantly bias the analysis away from solutions which may have a large impact on other areas (i.e. economic and environmental factors). Therefore, this metric was not used

(i) Secure livelihoods

PHL reduction interventions can improve livelihoods in three ways. Firstly, SHFs could achieve higher incomes from increased volumes, improved quality, or a combination of both. Secondly, margins across the value chain could be improved as a result of better quality crops. Thirdly, more stable incomes could be attained through an improved ability to plan volumes and prices.

The evaluation criteria used are expressed in Figure 3 below.

Figure 3: Evaluation Criteria (Secure Livelihoods)



(ii) Revalue ecosystems

As mentioned earlier, when environmental resources (particularly land and water) are used to produce crops that are not sold the result is wasted resources. Reducing PHL means that for every ton of crop sold, fewer resources as a percentage of output are used. Some PHL reduction technologies by their nature may improve efficiency by requiring less use of land, water or fertilizers in addition to reducing losses.

These evaluation criteria are detailed in Figure 4 below.

Figure 4: Evaluation Criteria (Revalue Ecosystems)

	Criteria	Evaluation Criteria Components
Revalue Ecosystems	Water Consumption	$\left(\begin{array}{l} \text{Post-intervention} \\ \text{volumes of water} \\ \text{used per ton} \end{array} \oplus \begin{array}{l} \text{Post-intervention} \\ \text{quantity of crops} \\ \text{sold} \end{array} \right) = \left(\begin{array}{l} \text{Pre-intervention} \\ \text{volumes of water} \\ \text{used per ton} \end{array} \oplus \begin{array}{l} \text{Pre-intervention} \\ \text{quantity of crops} \\ \text{sold} \end{array} \right)$
	Agricultural Land Usage	$\left(\begin{array}{l} \text{Post-intervention} \\ \text{land area used} \\ \text{for agriculture} \end{array} \oplus \begin{array}{l} \text{Post-intervention} \\ \text{quantity of crops} \\ \text{sold} \end{array} \right) = \left(\begin{array}{l} \text{Pre-intervention} \\ \text{land area used for} \\ \text{agriculture} \end{array} \oplus \begin{array}{l} \text{Pre-intervention} \\ \text{quantity of crops} \\ \text{sold} \end{array} \right)$
	Fertilizer Usage	$\left(\begin{array}{l} \text{Post-intervention} \\ \text{quantity of} \\ \text{fertilizer used} \end{array} \oplus \begin{array}{l} \text{Post-intervention} \\ \text{quantity of crops} \\ \text{sold} \end{array} \right) = \left(\begin{array}{l} \text{Pre-intervention} \\ \text{quantity of} \\ \text{fertilizer used} \end{array} \oplus \begin{array}{l} \text{Pre-intervention} \\ \text{quantity of crops} \\ \text{sold} \end{array} \right)$
	Greenhouse Gas Emissions	$\left(\begin{array}{l} \text{Post-intervention} \\ \text{carbon} \\ \text{equivalent} \\ \text{emissions} \end{array} \oplus \begin{array}{l} \text{Post-intervention} \\ \text{Post Harvest} \\ \text{Loss} \end{array} \right) = \left(\begin{array}{l} \text{Pre-intervention} \\ \text{carbon} \\ \text{equivalent} \\ \text{emissions} \end{array} \oplus \begin{array}{l} \text{Pre-intervention} \\ \text{Post Harvest} \\ \text{Loss} \end{array} \right)$

(iii) Advance health

A reduction in PHL for more nutritious crops (e.g. fruits and vegetables) has a greater impact on nutritional security than for less nutritious crops (e.g. grains). Further, some PHL-reducing technologies (particularly for dry crops) typically also reduce toxins (in particular, aflatoxins), which can have significant long-term health benefits.

The ratings used for these qualitative criteria are shown in Figure 5.

Figure 5: Evaluation Criteria (Advance Health)

	Criteria	Evaluation Criteria Components
Advance Health	Nutritional Value of Products Hitting the Market	$\left(\begin{array}{l} \text{Likely change to post-} \\ \text{intervention volume,} \\ \text{diversity of nutritional} \\ \text{products} \end{array} \right) \equiv \left(\begin{array}{l} \text{Relative range from 1 to 10; 3) Focus on less nutritious} \\ \text{staples, cereals; 7) Focus on Fruits \& Veg; 9) Focus is} \\ \text{Fruit \& Veg and other crops e.g. legumes and cereals} \end{array} \right)$
	Toxins Hitting the Market	$\left(\begin{array}{l} \text{Likely change to post-} \\ \text{intervention Toxins} \\ \text{hitting the market} \end{array} \right) \equiv \left(\begin{array}{l} \text{Relative range from 1 to 10; 1) Minimal reduction in} \\ \text{toxins; 5) Significant reduction in toxins; 10) Near-} \\ \text{complete reduction in toxins} \end{array} \right)$

3.2.2. Estimating a Solution’s Cost

The relative costs of solutions must also be considered to arrive at comparable ROI figures. To allow for fair comparison, as well as account for inevitable data gaps, only direct costs of solutions (e.g. the cost of bags, containers, building a warehouse etc.) were considered and not additional overheads that form part of implementation (e.g. utility costs). The costs of solutions have an important bearing on their relative ROI, which in turn affects how decisions might be made about them. Some solutions require greater capital investment to reduce losses, although this loss reduction could be significant (e.g. newer technologies such as Liquid Air allow for lower energy cooling in remote locations and could fundamentally change the cold storage chain in SSA). Conversely, a solution that appears to have relatively lower absolute impact (e.g. heavy molded plastic containers), could have a relatively high ROI due to its low cost, and thus achieve greater loss reduction and/or impact on the key issue areas per dollar spent.

3.3. ROI Analysis Outputs

Table 2 below presents the rankings from the ROI analysis based on the two metrics of impact defined above. It is notable that the ranking can differ quite significantly depending on the metric used. This is due to a variety of factors that drive impact including the crops and geographies affected by each solution (e.g. heavy molded plastic containers only impact perishables, whereas ZeroFly Bags only impact dry crops). Since driving impact on the triple bottom-line as well as the overarching goal of reducing PHL are important, solutions that rank highly with respect to both metrics are prioritized.

Table 2: Ranking of Solutions from ROI Analysis

PHL Solutions	Impact ROI Rank (Balanced View) ¹	Tons Wasted ROI Rank
Heavy Moulded Plastic Containers	1	4
Gum Arabic Coating	2	9
Warehouse Receipts System	3	7
ZeroFly Bags	4	8
Contract Farming	5	17
Direct Sourcing	6	1
Growtainers	7	18
Plastic Silos	8	10
SuperGrain Bags	9	12
Metal Silos	10	11
Collection Centres	11	5
Supply Chain Technology Platforms	12	16
Mobile Processing Units	13	2
Mobile / Solar Drying	14	6
Graters and Pressers	15	3
Low Energy Cooling	16	14
Liquid Air Refrigeration: Cold Storage	17	13
Liquid Air Refrigeration: IQF Freezing	18	15

Source: Monitor Deloitte Analysis

Note: ¹Several Impact ROI scores were calculated with different weightings for each of the issue areas. The balanced view gave equal weighting to each of the issue areas

The solutions that rose to the top in terms of one or both metrics are presented in Table 3 along with a brief explanation as to the key factors that drove its relatively high ROI.

Table 3: Rationale for Prioritized Solutions

PHL Solutions	Rationale
Heavy Moulded Plastic Containers	Reduces PHL during transporting and handling of nutritious, perishable foods; inexpensive to manufacture and buy
Gum Arabic Coating	Reduces PHL at the storage stage and improves availability of relatively nutritious foods; relatively inexpensive
Warehouse Receipts System	Reduces PHL at the storage stage and assists SHFs in avoiding price troughs; upfront costs can be spread over many years
ZeroFly Bags	Reduces PHL at the storage stage and toxins hitting the market; relatively competitive technology cost
Contract Farming	Increases and stabilizes incomes, while also improving availability of fruit and veg; increased production increases PHL
Direct Sourcing	Improves market linkages, which improves incomes and reduces storage losses; applicable to many crops
Growtainers	Relatively expensive, however may result in significantly more efficient use of agricultural inputs as well as higher yields
Collection Centres	Relatively effective at reducing PHL, improving incomes, advancing health, and applicable across a wide range of crops
Mobile Processing Units	Reduces PHL significantly, however limited to grains and cassava and relatively expensive

Source: Monitor Deloitte Analysis

4. Considerations for Implementation of PHL Reduction Solutions

The need for a market-led systemic approach to addressing PHL has become apparent from past failures and emerging successes. The technology-push approach that dominated PHL-related activities in the 1970s and 1980s is still prevalent, but has largely not had the desired impact on loss reduction. Traditionally, loss reduction was seen as a stand-alone intervention for improving food security. Triple bagging of cowpea in West and Central Africa as well as the mechanized harvesting and cleaning of equipment to reduce losses for wheat and maize in Uganda are good examples of recent interventions that have followed this approach. Despite some success at reducing on or near-farm losses, many interventions of this type have faced challenges in: (i) achieving adequate adoption, (ii) attracting sufficient long-term financial support, (iii) achieving sustainability, (iv) achieving impact at scale and (v) ensuring food produced makes it to consumers.

There has been increasing consensus that market-oriented approaches are needed. Market demand provides an important incentive for large-off takers to actively participate in PHL interventions and forms the basis for a further reaching incentive system. Demand also provides an important guide-post for prioritizing crops, technologies and countries where interventions could gain traction, become sustainable and achieve greatest impact.

4.1. Interventions to Reduce PHL

To optimize existing value chains for reduced PHL, a combination of complementary activities is recommended. As Figure 6 illustrates, this requires models that integrate the following four Ps: Products (technologies), Processes (procurement channels), Producers (farmers) and Pricing & Payment (financial intervention).

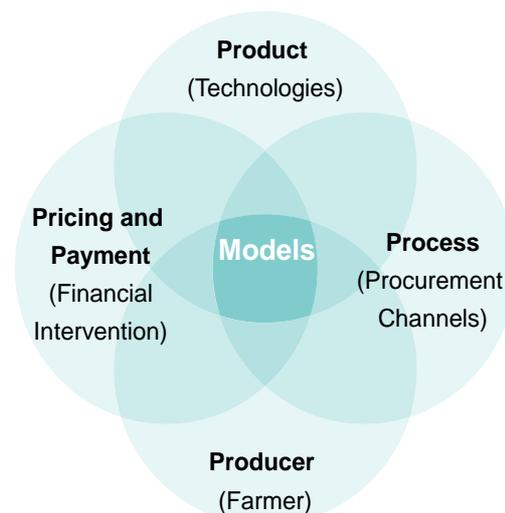
Figure 6: Key Elements of a PHL Intervention

4.1.1. Product Interventions

Product interventions, or PHL technologies, can be adapted into existing and new agricultural supply chains.

Promising technologies for loss reduction can be categorized into near-term technologies and high-potential new technologies. The former typically includes more traditional solutions or those that have gained significant traction over the last few decades.

Examples of a few leading technologies include hermetic bags, heavy mold plastic containers, mobile processing units and metal silos.



Source: Monitor Deloitte Analysis

These solutions can be produced at scale and are relatively easy to implement in that they leverage existing agricultural practices of smallholder farmers. Their efficacy (in terms of loss reduction as well as economic, social and environmental impacts) and relatively low cost per ton to operate drives up their ROI relative to other interventions.

High-potential new and innovative technologies include Gum Arabic Coating as an on-farm storage solution, and sustainable and affordable cold chain logistics solutions such as liquid air and low-energy cooling technologies (e.g., CoolBot, Intelligent Ice, etc.).²⁰ These technologies may require additional investment and development before they can be introduced into existing agriculture supply chains.

4.1.2. Process Interventions

Process interventions attempt to link producers to reliable market demand. When structured correctly, these arrangements can increase income for farmers and create more reliable supply for buyers. High-potential procurement channels include contract farming, direct sourcing and collection centers.

Contract farming involves the production of crops on the basis of a contractual agreement between a buyer (e.g. retailers, processors) and farmers. The agreements typically encompass the provision of high quality agricultural inputs and technical assistance. The solution provides for more consistent incomes for SHFs by guaranteeing a buyer and a sales price. Although contracts can theoretically be drawn-up for any crop variety, this solution is most applicable for high-value, high-margin crops such as fruit and vegetables that offer greater incentive for the significant capital investment made by off-takers.

Direct sourcing is a less capital intensive process intervention. These are agreements (often without formal stipulations of quantity and quality) between large buyers (e.g. processors, retailers) and farmers to purchase crops directly from farms. The exclusion of an intermediary allows for farmers to potentially receive a greater proportion of the market price. The channel also provides for more efficient logistics and reduced losses by reducing points in the supply chain in which the product changes hands.

Collection centers provide less direct access to large buyers, but can still be very effective in linking farmers to off-takers. These are aggregation points that link farmers to buyers, and primarily offer processing, grading, storing, and packing facilities. The centers improve SHFs' income by providing more secure markets; however, they do not always guarantee consistent off-takers.

Secondary markets are also of critical importance for reducing PHL, particularly in instances of contract farming or direct sourcing. Large volumes of crops are often rejected by primary off-takers if they do not meet stringent quality requirements. This can result in further crop losses if alternative procurers or uses for the crops are limited or unavailable. Intentional development and management of secondary markets could help to significantly reduce PHL. A number of approaches can be taken to develop these markets including establishing direct linkages between secondary off-takers and farmer organizations, primary off-takers or even special purpose vehicles (SPVs) that consolidate rejected crops and distribute them to secondary off-takers. Further, potential secondary off-takers should be sought, engaged early-on and included in crop value chains. These may include hotels, restaurants, farmer markets, wholesalers and retailers, local processors, etc.

²⁰ While Intelligent Ice was not included in the ROI analysis, it is considered here as a potential alternative to CoolBot if investments in development allow it to be marketed.

4.1.3. Producer Interventions

Past interventions demonstrate the importance of capacity building and other methods to ensure skills-transfer. Farmer and distributor training on the benefits, handling, and use of technologies and processes is important for ensuring adoption, correct usage and thus achieving the desired impact. For example, incorrect usage of triple-bags could result in expensive distribution but limited reduction in on-farm crop infestation, toxicity and losses. It is important to ensure that users (typically SHFs) undergo sufficient practical training (including demonstrations) to understand how to use the technologies as well as the importance of proper use.

Farmer groups that facilitate aggregation are often instrumental in implementing producer interventions given their understanding of local farmer contexts, their credibility with SHFs, and their broad access to farmers in remote regions.

4.1.4. Processing and Payments Interventions

Financial interventions will be required to de-risk investments and facilitate adoption of technologies, particularly amongst resource-constrained SHFs. Potential funding can be broadly classified as financing for the private sector and financing for farmers.

Private sector actors, such as technology manufacturers, may require funding to develop production and distribution capacity. These firms are often good candidates for debt or mezzanine financing given the asset bases and favorable risk profiles they can leverage. They could also benefit from purchase-guarantee contracts to de-risk investment in new areas.

In contrast, SHFs typically have limited access to funding. Three categories of funding could be considered to address this funding gap –

- (i) **Debt financing** may be offered by some traditional financial institutions. The risk appetite for these lenders often excludes many SHFs; however there is growing interest by banks to develop specialized agricultural funds. One option to mitigate risk and encourage greater extension of credit is to drive the aggregation of SHFs. Pooling assets and productions would allow SHFs to disperse risk.
- (ii) **Value chain financing** could look to increase the flows of financing through a value chain by improving funding at specific points. This arrangement works best where there is strong end-market demand, as well as transparency, trust and repeated inter-firm transactions. In this scenario, the risk profile of large value chain actors, such as primary off-takers, can be leveraged to provide capital that flows through the value chain to SHFs. Three main types of vehicles may be used in such an arrangement:
 - The provision of credit, savings, guarantees or insurance to or among value chain actors.
 - The creation of strategic alliances through financing extended by a combination of value chain actors and financial institutions.
 - The offering of tools/services to manage price, production or marketing risks.

This type of financing offers multiple potential benefits. Value chain finance can enable the sustainable delivery of services and technologies. These arrangements can also improve working relationships (e.g. between buyers and suppliers) and facilitate intra-chain information that lowers the actual or perceived risks of lending. Perhaps most importantly, a successful demonstration may encourage larger-scale players and formal financial actors to provide further agricultural finance.

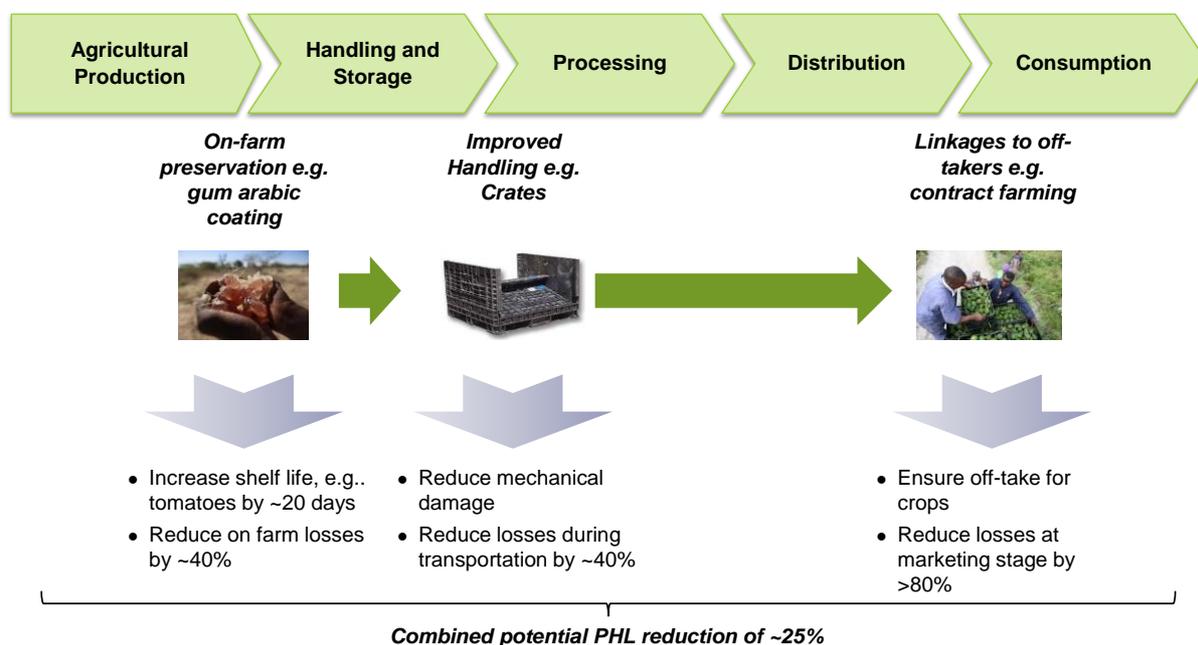
The viability of many value chain finance mechanisms can be limited by low or unreliable end-market demand, mistrust among actors, and an unsupportive regulatory and policy environment. These challenges, along with contract enforcement to mitigate issues such as side-selling are pivotal to the success of buyer-based finance mechanisms.

- (iii) **Micro leasing** offers SHFs an opportunity to access relatively more expensive technologies, including metal and plastic silos, mobile processing units, or other expensive processing equipment. In this model farmers would not be required to purchase and maintain the technologies themselves, but would rather have access to them in a fee-for-use arrangement.

4.2. Systemic Nature of Post-Harvest Losses & Implication for Implementation of PHL Interventions

Because the challenge of PHL is inherently systemic, PHL interventions must be interconnected along the value chain. The combination of inter-connected technologies and procurement channels along the value chain will reduce loss more effectively and provide more impact than a single technology. For example, a combination of Gum Arabic Coating as an on-farm preservative for fruits and vegetables like tomatoes, with an improved handling and transport technology such as heavy-molded plastic containers, and a secure market channel such as a contract farming scheme, would reinforce gains made at various stages of the value chain resulting in significantly less loss than with any individual solution. This is depicted in Figure 7 below. It is, therefore, strongly recommended that an integrated combination of complementary PHL solutions should form the basis of future PHL interventions. This will also play an important role in facilitating uptake of technologies and enhancing sustainability of interventions.

Figure 7: Illustrative cumulative impact of integrated technologies



Source: Khaliq, et al, 2009; Aba, et al, 2012; Melle and Buschmann, 2013; Monitor Deloitte Analysis

Multiple activities need to occur simultaneously to successfully implement PHL reduction interventions. These activities should be guided by lessons learned and key insights gained from decades of work aimed at reducing food loss, including –

- (i) **Awareness of and access to solutions is key.**

Many farmers find it difficult to access some potentially impactful interventions due to upfront costs and poor distribution networks. High costs for many solutions (e.g. mobile processing units) prohibit SHFs from individually owning a PHL product or technology. Similarly, the dispersion of SHFs in remote, disparate rural locations makes distribution a key challenge. Leveraging existing retail channels for distribution and providing innovative finance and capacity building are important considerations for alleviating this challenge.

(ii) Supply chains and production capacity for the solutions themselves need to be developed.

Building the local capacity to produce and maintain technologies is important for creating scale and sustainability. In Central America, the PostCosecha program saw transformational results by investing in local manufacturing capacity through existing tinsmiths to build new grain silos. Between 1983 and 2003 (post the initial silo rollout) over 336,000 tons of grain were saved, \$100 mn additional income for farmers and \$12 mn profit by 900 tinsmiths was achieved.²¹

(iii) Stakeholders may not see investments in food loss reduction as a high-return activity relative to other opportunities.

Investments in these solutions may not be as attractive as other methods to obtain reasonable returns for key market actors.

Although the monetary costs from the loss (e.g. forgone income) over the medium- to long-term often exceed the monetary costs of putting in place storage solutions, processing solutions, etc., these investments tend to compete with others such as production-improvements investments. Thus any investment in PHL reduction will need to be economically viable, sustainable and include clear incentives for various actors.

(iv) Working within current systems and leveraging existing infrastructure could reduce complexity associated with implementation of solutions; however, current system failures will need to be addressed.

Current crop supply chains typically consist of farmers whose produce is aggregated through formal or informal farmer groups to access some form of primary off-taker, for example a local processor, retailer or multi-national cooperation. Established supply chains of this nature provide a good base to introduce PHL reduction interventions as well as engage key stakeholders such as agro-dealers, farmer associations and off-takers. However, a number of common challenges in these systems should be addressed. As discussed above, low rates of technology adoption typically occur due to prohibitive costs and behavioral constraints. Secondly, there are often limited outlets for products that do not meet primary market requirements. Broken or non-existent linkages to secondary markets can lead to significant PHL. Thirdly, those who stand to benefit most from reduced PHL are not necessarily those that are in a position to implement interventions. For example, large multinational corporations (MNCs) are able to operate at a profit without needing to reduce PHL and, hence, the incentive to do so is not particularly strong, while on the other hand, farmers could stand to benefit significantly from reduced PHL, but are not equipped to intervene.

²¹ Fischler, 2011, 'PostCosecha Programme, Central America: Final Report'. Available at: https://www.eda.admin.ch/content/dam/deza/en/documents/Laender/resource_en_202650.pdf

5. Models for PHL Reduction Intervention

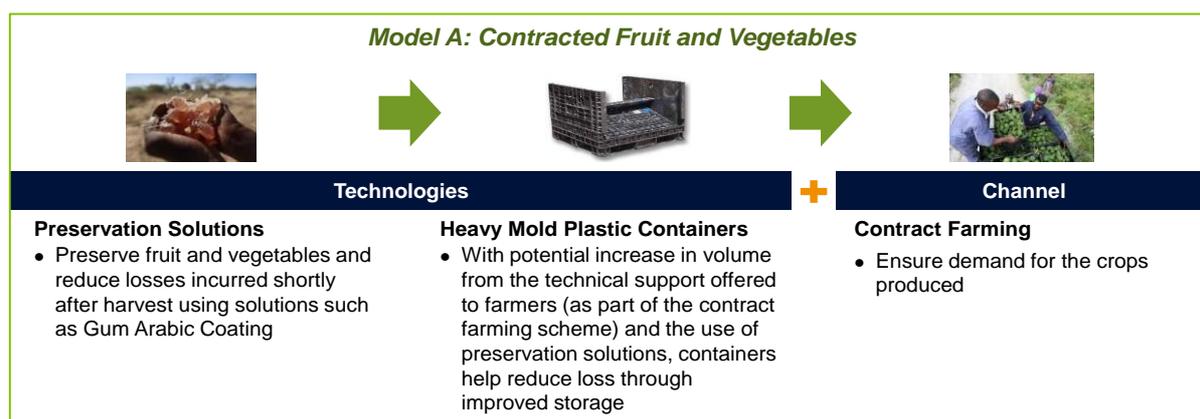
As described above, solutions to reduce post-harvest losses should be implemented collectively and not in isolation given the systemic nature of losses in agricultural value chains. Three illustrative models, representing different combinations of inter-connected solutions were constructed based on the described ROI analysis and an assessment of individual solutions. These three models each have varying benefits and trade-offs. They are: (1) Contracted Fruit & Vegetables Model, (2) Processed Food Crop Model, and (3) Improving Grain Availability Model.

5.1. Contracted Fruit and Vegetables Model

This model is a combination of on-farm preservation solutions such as Gum Arabic Coating, heavy molded plastic containers and procurement of crops either through contract farming or collection centers as illustrated in Figure 8

The first step in rolling out the model is to preserve fruit and vegetables, and reduce losses normally incurred in storage, through solutions such as Gum Arabic Coating. The coating delays ripening significantly; for example, it increases the shelf-life of tomatoes by up to 20 days. Next, using plastic containers for storage and handling could help reduce losses incurred during transport and handling. Heavy molded plastic containers can reduce losses incurred during the transportation of perishables by up to 40% compared to traditional transport mechanisms (e.g. bags).²² These containers are relatively inexpensive at ~ \$2.40 each and have a useful life of four years.²³ While farmer ownership of the containers is one option, other financing options include ownership by a large off-taker or third party intermediary (e.g. farmer organizations) in order to secure greater quality and quantity of supply. The third step in this model is to ensure demand for the crops produced through contract farming or well organized collection centers. Contract farming has the added advantage of inputs and other technical support from off-takers, which can help ensure that preservation and storage solutions are used correctly.

Figure 8: Illustrative Horticulture PHL Reduction Model



Source: Monitor Deloitte Analysis

²² Aba, I., Gana, Y., Ogbonnaya, C. and Morenikeji, O., 2012, 'Simulated Transport Damage Study on Fresh Tomato (*Lycopersicon Esculentum*) Fruits'. Available at: <http://cigrjournal.org/index.php/Ejournal/article/viewFile/2035/1613>

²³ Ibid

This combination of solutions aligns well with existing MNC activity regarding fruits and vegetables. Large agricultural businesses are already engaged in contract farming and collection centers for these high margin crops and preservation and storage / transportation technologies are appropriate given strict production and handling requirements. This type of model would not only reduce losses, but could have significant impact on improving the incomes and consistency of cash inflows for SHFs as well as the availability of nutritious foods in domestic markets (if contracts are not solely for export purposes). Intentional secondary market linkages could also be developed for crops (or their derivative products) that do not meet specifications.

One downside of this intervention model relates to widespread adoption and scale. A relatively smaller proportion of SHFs are involved in horticulture farming compared to other types of crops (e.g. grains) and, at least initially, low-income SHFs may not have the resources or capacity to become involved in contract farming schemes.

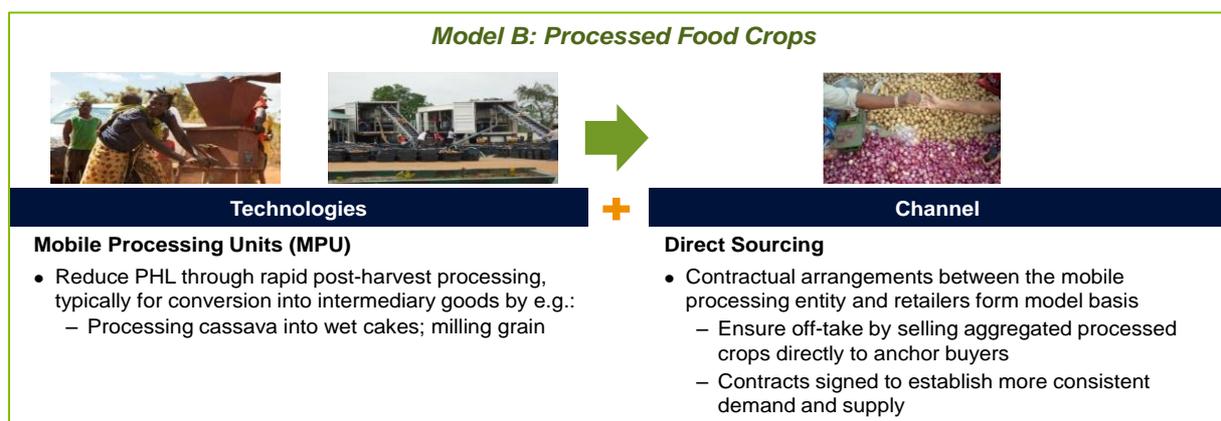
5.2. Processed Food Crops Model

This model combines on-farm and near-farm processing via MPUs with direct sourcing. The model seeks to ensure an end-market for crops, while reducing PHL at points of storage and processing along the agricultural value chain, as illustrated by Figure 9.

Rapid, on- or near-farm post-harvest processing could significantly reduce PHL. For example, processing can improve shelf life of highly perishable cassava by 12 months (the crop typically perishes within 48 hours in its raw state). The upfront cost of MPUs can be prohibitive for the average SHF. However, MPUs have long useful lives and can process a significant volume of crop thus lowering their per unit cost of operation and making them ideal for lease-based arrangements (i.e. by processors, entrepreneurs, farmer organizations or technology suppliers).

This model looks to ensure off-take by selling aggregated processed crops directly to anchor buyers. By reducing the need for storage, the combination of on-farm processing and selling to anchor buyers has the potential to reduce PHL by as much as 80%.²⁴ Forward supply agreements not only drive consistent supply for off-takers but also help SHFs secure consistent incomes.

Figure 9: Illustrative Staple Crop PHL Reduction Model



Source: Monitor Deloitte Analysis

²⁴ Monitor Deloitte Analysis

5.3. Improving Grain Availability

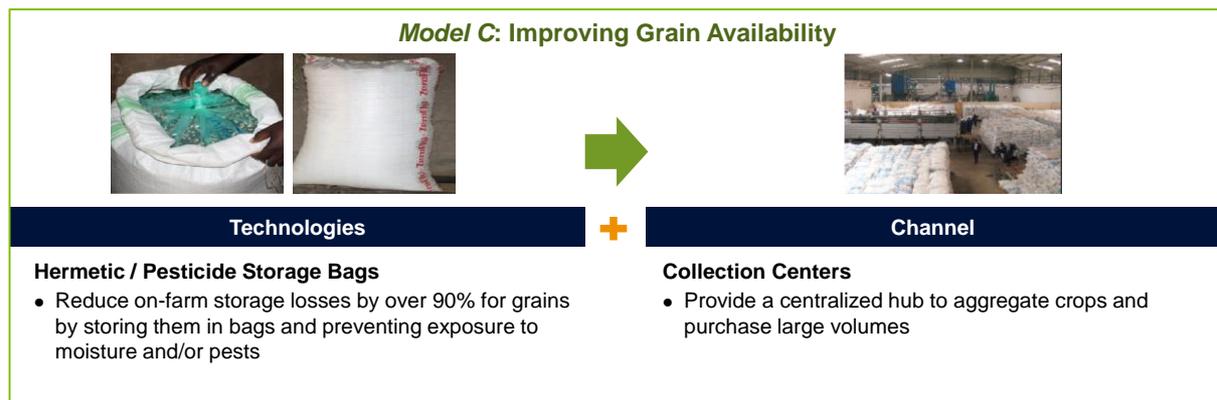
This model focuses on reducing losses of grains through a combination of improved on-farm storage together with enhanced grading capability and market linkages at collection centers. Figure 10 provides an illustrative view of the Grain Quality Improvement model.

On-farm storage losses for grains can be reduced by over 90% by storing grains in hermetic or pesticide bags and preventing exposure to moisture and/or pests.²⁵ These bags can also significantly reduce toxin levels by reducing moisture content below 13% (level at which mold becomes a concern for grains) and increasing shelf-life by over 6 months.²⁶ These bags can however be quite expensive for the average SHF at a cost of ~ \$3 / bag (up to 100kg capacity), with a life span of only 2-3 harvests.²⁷ Collection center operators could be incentivized to absorb some of these upfront costs, through mechanisms such as credit advancements, given the promise of higher quality grain.

The model requires the provision of a centralized hub or collection center to aggregate crops and facilitate the purchase of large volumes. Handling and storage of grains at the center can reduce losses by up to 65%.²⁸ Collection centers allow for an efficient link with farmers' produce, allowing off-takers to avoid dealing with individual food business operators. Furthermore, grading at these centers enables differentiated pricing and price premiums to be charged for higher quality crops. These price premiums could incentivize farmers to produce higher quality crops and thus play a key role in the wide scale adoption of bags.

The model is most applicable for grains and dry crops, which are often staples and important for food security across SSA. As such, it has potential for widespread economic and social impact, although the impact on nutritional security and diversity is less than in the other illustrative models. Economies of scale in this model are likely to be achieved by attracting large buyers to collection centers. Institutional buyers (e.g. World Food Program) and large private-sector buyers (e.g. wholesalers, processors) would be important in this regard. In order to attract these buyers, grading and quality requirements would need to be met. In turn, this would encourage the adoption of improved storage bags to ensure adherence to quality standards.

Figure 10: Illustrative Grain PHL Reduction Model



Source: Monitor Deloitte Analysis

²⁵ Costa, S., 2014, 'Reducing Food Losses in Sub-Saharan Africa'. World Food Program. Available at: http://documents.wfp.org/stellent/groups/public/documents/special_initiatives/WFP265205.pdf

²⁶ Ibid

²⁷ Ibid

²⁸ USAID, 2011, 'Market Linkages Initiative: Lessons Learned From Integrating Smallholder Farmers into Commercial Markets in East Africa'. Available at: http://www.competeafrica.org/Files/White_Paper_USAID_COMPETE_on_SF_models_May_2011_FINAL_compressed.pdf

6. Conclusion and Guiding Principles

It is evident that more needs to be done to meet the consumption demands of SSA's growing population. A concerted focus on production growth, while needed, is not sufficient. PHL reduction interventions provide a unique opportunity to not only address food losses, but also positively impact the lives of SHFs, other value chain actors and society at large; they improve incomes, reduce toxicity of foods, create greater nutritional diversity and improve the efficiency of natural resource usage.

However, PHL reduction solutions will not achieve these intended benefits when implemented in isolation. An integrated and systemic approach is required to achieve significant and sustainable reduction in crop losses. Stakeholders should look to refine and optimize existing value chains for PHL reduction. This will require simultaneous improvements to, and alignment of, key components of agricultural value chains, including –

- Aggregation and creation of producer groups to promote the benefits associated with economies of scale such as aggregation of produce, access to post harvest technologies, and lower production costs per unit of crop sold.
- Access to products / technologies that reduce PHL
- Synchronization of technologies and aggregation platforms with procurement platforms to ensure uptake
- Supportive funding options to enable purchase of PHL solutions and processing technologies
- The integration of technology supply chains into crop value chains

To successfully implement these interventions, and in particular drive adoption of PHL technologies, four key areas need to be addressed; (i) Awareness, (ii) Affordability, (iii) Access and (iv) Adoption

- (i) Awareness – SHFs are often unaware of available solutions. Practical demonstrations and pilot programs allow SHFs to see tangible results and improve general awareness of technologies.
- (ii) Affordability – Affordability is also a key barrier for SHFs. Innovative financing could help to transcend traditional hurdles such as limited financial collateral and limited credit history. Funding could take the form of credit extension, value chain financing, revolving funds and even micro-leasing.
- (iii) Access – Access to technologies may also limit the adoption of PHL reduction technologies. Improving physical infrastructure as well as leveraging procurement and retail channels to distribute technologies could play a pivotal role in improving access.
- (iv) Adoption – In addition to the factors above, adoption may also be influenced by farmer perceptions as well as other factors. A good understanding of user concerns and priorities should aid greater adoption.

The challenge to significantly reduce PHL is not insurmountable. While a number of the potential inventions and solutions have been assessed, the problem will be addressed when multiple actors are mobilized through market-driven motivations. But in order to ensure that the problem is addressed *sustainably*, consumer demand and clearly defined incentive systems will need to help guide decision-making. These incentives should be clearly linked to core stakeholder interests. This will best occur through collaborative development of crop-specific strategies for specific countries that bring multiple stakeholders to the decision-making table: companies, government, smallholder farmers, other value chain actors, and the donor community.