FINAL REPORT
Volume One

Investigation of Issues and Challenges Facing African Smallholder Farmers and Highest Potential Intervention Points in Reducing Waste and Spoilage in African Food Systems

Prepared for:
Alliance for a Green Revolution in Africa (AGRA)

Submitted by:
Abt Associates
4550 Montgomery Avenue
Suite 800 North
Bethesda, MD 20814

May 31, 2014

This study was prepared over a three-month period between March and May of 2014 by a multidisciplinary team assembled by Abt Associates Inc at the request of AGRA.

Fieldwork was carried out under the supervision of Principal Associates Eliot Masters and John Lamb. Country-level research was led by Associates Dianna Gillespie (Ethiopia). Daniel Sarpong (Ghana), Betsy Ness-Edelstein (Kenya), Mikal Davis (Mozambique), Kirsten Heil (Nigeria), Bassirou Sarr (Senegal) Brad Dunn (Tanzania), Report writing was carried out under the supervision of Principal Associates Ken Hoadley and John Lamb. Administrative oversight was provided by Sr. Finance and Contract Administrator Veronica Ramos.

The Abt Team is very grateful to the many (nearly 100) African agricultural experts, development specialists, government officials, smallholder farmers, and women who shared their time, energy and knowledge through individual and group interviews, as well as expert/stakeholder workshops in each of seven countries.

We would also like to express appreciation as well to AGRA in general for entrusting us with this responsibility, and specifically thank David Nyameino for his unfailing support and guidance in the role of program coordinator.

We hope that the contents of this report fairly reflect and summarize the many insights that were freely provided. Any errors of commission or omission are entirely ours.

This work does not necessarily reflect the views of AGRA as client, nor of Rockefeller Foundation as principal provider of financial support for this effort.

Respectfully yours,
Abt PHL Team

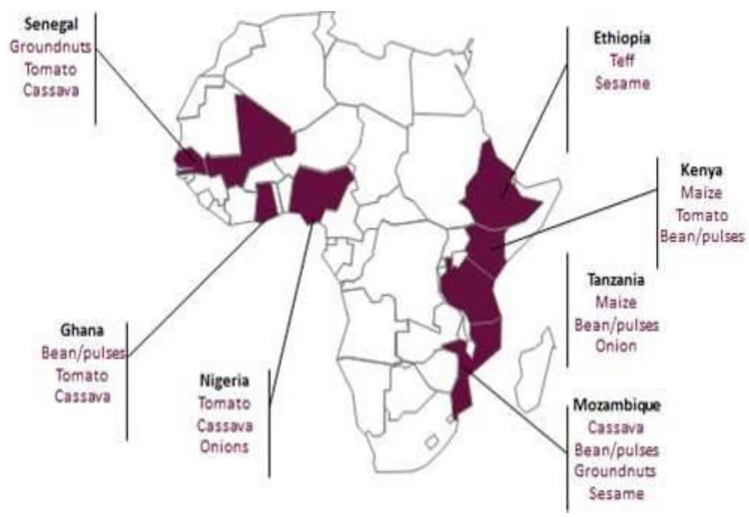
1. Introduction

The Alliance for a Green Revolution in Africa (AGRA), with support from the Rockefeller Foundation, has selected partners to address a set of targeted research questions relating to reducing waste and spoilage ("PHL" for short) in food value chains.

Abt Associates Inc. was selected to carry out an in-depth investigation of waste and spoilage issues and challenges facing African Smallholder Farmers (SHF) in selected crop-based value chains and seven countries, in order to then identify high-potential intervention points.

1.1 Country and Value Chain Coverage

As defined during the Nairobi inception meeting, the focus country and crop combinations for this study are shown in the graphic below.



As readers will note, cassava, tomatoes, and beans/pulses were picked for four countries; groundnuts, onions, maize, and sesame for chosen for two countries; and teff for Ethiopia alone.

1.2 Scope of Work

1.2.1 Issues to Address

The Terms of Reference called for the contractor to address two main issues, which are repeated (in italics) below, and are then briefly discussed:

1) *The need to enhance understanding about factors driving broad adoption and proper use of post-harvest solutions, with a particular contribution to knowledge regarding the creation of new employment opportunities*

In the development literature, there is considerable research on and hypotheses about, what drives smallholder farmers (SHFs) to adopt or not adapt solutions to agricultural challenges. Explanatory factors often suggested include: (a) lack of awareness of the specific causes and potential solutions:

(b) absence of data; (c) adherence to customary practices; (d) lack of credible role models; (e) lack of productive resources; (f) limited access to capital; (g) shortage of labor; (h) difficult access to required inputs; (i) adverse incentive structures; and/or (j) general risk aversion. It is generally agreed that all of these factors play a role in adoption of improvements, but to varying degrees that depend on the specific situation.

Many different studies have concentrated on postharvest loss reduction. Generally they focus on a limited number of commodities, which for Sub-Saharan Africa tend to be food security crops that are widely consumed in the country of interest. Typically such efforts try to identify where PHLs occur, what is their approximate magnitude, what the alternative interventions might be, what are their likely benefits and costs, and how prevalent is the application of those solutions by SHFs.

However, field research in the postharvest loss (PHL) area has tended to focus on assessment more than mitigation, and when specific solutions are examined, what is often missing is in-depth understanding of the farmer's perspective with regard to specific PHL challenges and potential interventions. Since researchers tend to be more highly educated, they may apply concepts such as percentage of loss that may not fit the vocabulary or numeracy level of SHFs, who tend to think in terms of more or less, numbers of bags, change in money received, or availability of basic grains during the hungry months. When researchers are not from the same area, they may miss the significance of tradition, cultural norms, or tribal leadership. Since the research is often done without actual measurement, and long after harvest, sale, and consumption, the accuracy of perceptions data may be questionable.

Since many post-harvest activities depend on women, certain additional questions have to be considered such as convenience, distance, demands on time, effects on familial responsibilities, gender roles, and sometimes religious norms (e.g. in Northern Nigeria). On the other hand, greater adoption of certain PHL mitigation measures may actually create additional opportunities for paid employment or at least cause greater income to accrue to and be controlled by women, which may have positive spillover effects on household livelihoods, maternal and child health, and/or family nutrition.

For all those reasons, the scope of work was designed to elicit more complete information—including behavioral, and mostly from smallholder farmers and women-- that would help to more effectively promote adoption of solutions for waste and spoilage reduction among SHF.

2) *The nature and location of the highest potential intervention stages along the food supply chain in various countries for reducing waste and spoilage.*

By definition the complete supply chain for food runs from farm to fork. The phrase "chain" notwithstanding, agri-food supply systems actually constitute networks, with nodes that interconnect in complex ways. There may be more than one form and presentation of significance, such as mango juice, concentrate, and pulp as opposed to fresh mangoes. Destination markets may be nearby, elsewhere in the same country, farther away but within the same region, or in foreign lands. It follows that there are multiple vectors from supply source to final point of sale. Some pathways from source to end-market are more economically important than others. All of this complicates PHL mitigation.

Where to start and finish PHL assessment is a material question. Despite the term "post-harvest loss", many actions taken before harvest affect the quantity and quality of useable output. It is also understood that ending the analysis at the first delivery to another's custody is inadequate, since other actions taken after harvest (such as collection, aggregation, and intermediate storage) by non-farm actors such as traders, truckers, or marketing agents, actually affect final sale prices, marketing margins, hence profitability to farmers. For purposes of this study, the team concluded that it was appropriate to define "along the supply chain" to start at the point of field maturity when the product **could** be harvested (even if left longer), and then follow the products of interest along major channels of supply, including all stages of handling, storage, transport, processing, and distribution that might affect net returns to small farmers.

Whose supply? matters greatly. While RF and AGRA, along with most other donor agencies and host governments, are most concerned about smallholder production, significant volumes may be coming from larger operators, who tend to have more developed approaches to PHL reduction from which SHFs and development agencies can learn, and whose actions in the marketplace can greatly influence prevailing prices.

Where losses are greatest is also partly dependent on the business model that is in play. Subsistence vs. commercial farming operations tend to have different loss profiles. Whether marketing consists of simply selling on a spot basis to traders who may arrive unexpectedly, or delivering against a firm purchase contract, has much different implications for approaches to mitigation.

Those caveats notwithstanding, while the eight commodities selected for consideration vary considerably in their physiology and handling requirements, they all do pass through a similar sequence of stages as they move toward final markets. For analytical purposes, the team defined the following loss/intervention points as indicative, while recognizing that not all were relevant or significant for all crops:

- Post-production
- Harvesting
- Field drying (when applicable)
- Platform drying (when applicable)
- Threshing/shelling (when applicable)
- Winnowing (when applicable)
- Transport to packing shed
- Storage at the farm level
- Grading and sorting
- Handling and transport to first receiver
- Storage and handling at the trader level
- Processing (when applicable)
- Downstream storage (when applicable)

The concept of "highest potential" also warrants some discussion and clarification. Since post-harvest challenges can affect quantity, quality/condition of arrival, and/or marketability, it follows that returns on investment could be measured in terms of changes in useable or edible volume, selling price, or market acceptance. Alternative interventions may have different effects on any of those indicators, and a particular intervention might boost one indicator while not helping or even harming another. For example, tightening grades and standards may lower saleable volumes yet raise the selling price for first quality produce, and also precipitate sale of seconds to markets other than fresh.

At the same time, interventions have different upfront investments and different operational costs, not all of them measurable in monetary terms. For example, an intervention such as fumigation requires use of purchased inputs, which may be out of reach for the subsistence farmer, unless there is access to credit. Metal silos may require capital investment, while traditional mud silos require only labor. Use of hermetic triple bagging may seem less expensive than ultrahermetic bags, yet they may not last as long, may not discourage large grain borers, and may not retard aflatoxin formation.

Return on investment is also a function of time to realization of the benefits. For SHFs in particular, the magnitude of initial outlay in terms of money and effort may overwhelm the stream of expected later benefits, making the intervention impractical and unattractive.

Lastly, there is the matter of risk. Especially when the intervention is relatively unproven, uncertainty as to efficacy can impede adoption. Inappropriate use—such as opening sealed cocoons to extract some product—can also impede effectiveness. Since market prices are volatile, the incremental gain from holding product can also be uncertain. And of course, ambient conditions in the future are inherently unpredictable as well. Storing product in a flood-prone area may not be prudent.

Theoretically a comprehensive and rigorous approach to assessing the attractiveness of alternative interventions—including a matrix of objective functions, discount factors for time, and probability distributions to account for uncertainty—may be possible. Yet its complexity would overwhelm actual decision-making by SHFs, and in any case data availability and quality would always be challenging. Lacking that, for purposes of this particular study the instructions were to assess the promise of potential interventions by applying four simple filters: accessibility, affordability, adoption, and gender. Which is what we do below for selected interventions, and for more potential interventions in the country annexes presented in Volume Two.

1.2.2 Objectives and Sub-objectives

<u>Objective 1. Prioritize (by gender) smallholder (i) issues; (ii) challenges; (iii) skills; and (iv) capabilities</u>

Sub-objectives:

1) Characterize the PHL situation for designated crop/country combinations; and
2) Prioritize associated contextual and circumstantial challenges

Key Questions:

1) How aware of losses are smallholder farmers involved in the selected value chains? Which types worry them the most and why?
2) What are they currently doing to prevent or mitigate those problems and what else would they like to do?
3) What attitudinal and capacity factors inhibit greater awareness or action?

4) What are the main considerations smallholders have in deciding whether and how to act to reduce waste and spoilage along selected value chains?

5) What types of intervention and/or support (i.e. financial or technical) and/or incentives would stimulate further action?

Objective 2. Identify key crop value chain intervention points

Sub-objectives:

1) Identify and assess country-specific intervention opportunities, by specific crop and geographic area

2) Identify and assess technology-specific intervention opportunities, by specific crop and geographic area

Key Questions:

1) What are the country-specific intervention opportunities, by specific crop and geographic area? How do intervention opportunities vary between the targeted crops and geographic domains (i.e. different countries, selected source areas) and between those that remain distant and disconnected versus those that have access to markets and better infrastructure (areas that have rapidly accelerating infrastructure and market access or more remote areas)?

2) What are the technology-specific intervention opportunities by specific crop and geographic area?

The sub-questions to be addressed are:

1) What is the process from awareness to behavior change?

2) Are there any gender differences in the process from awareness to behavior change?

3) What cultural and environmental factors might be important?

4) What are creative ways to encourage waste and spoilage reduction behavior changes?

5) To what extent do waste and spoilage levels for a particular crop influence farmers' decision to cultivate it or not?

6) Do the income/production levels of SHF influence their waste and spoilage reduction practices?

7) What are the primary areas for training/knowledge for helping farmers avoid pre-harvest produce losses in both quality and quantity?

8) Are farmer organizations aware of and do they appreciate the magnitude of postharvest losses' effects on their incomes? How can they best be mobilized and what new capabilities are required?

9) What intervention points in the crop value chains will yield the best results (quantity and quality) in waste and spoilage reduction?

10) What are the gender issues to consider in technology design, adoption, and up-scaling?

11) What variations exit by country and crops in relation to intervention points and technologies for waste and spoilage reduction?

12) What technologies best provide opportunities for SHFs, especially women, to engage in waste and spoilage reduction?

1.3 Research Methodology

As agreed during the inception workshop, this effort groups the waste and spoilage referred to in the scope of work under the umbrella term "postharvest loss." The optic was to be limited to products grown for fresh use as human food, whether by small farmers themselves or via sale to local markets or processors for consumption by others. However, during execution of the study, it became evident that some analysis of **artisanal processing** (e.g. cassava chips and groundnut oil), **industrial uses** (e.g. tomatoes for processing) and **alternative markets for seconds** (e.g. maize for animal feed) had to be considered to reflect real concerns voiced by subject farmers.

In recognition of work done by others, the field work did not attempt to independently quantify actual losses for each country/crop combination and each stage of the main supply chains. Instead it looked to specialized information sources, secondary literature, and advice from locally knowledgeable economic and supporting actors to prioritize typical losses at each stage in the supply chains and to attribute them to major causes.

The study team—which consisted of a core of seven Abt Associates staff members, supported by 1-3 local agriculturalists in each target country--began in March of 2014 with a desk analysis of secondary literature (which was used to guide the fieldwork and is presented in annex form as a bibliography). We found that basic post-harvest loss data and associated information on most of the value chains selected is already available from various sources. These include a very recent multi-country study funded separately by AGRA, for which a consultative and validation meeting was held in Nairobi in early February 2014. Other particularly relevant efforts include the work done over the past decade by the African Postharvest Losses Information System (APHLIS); a new regional assessment for West Africa being undertaken by the Food and Agriculture Organization (FAO) and cooperating governments; the Landscaping Assessment just completed by Abt Associates with Bill and Melinda Gates Foundation (BMGF) funding; and the earlier Missing Food study at the World Bank done in cooperation with the Natural Resources Institute (NRI) and the FAO. However, it should be noted that the main sources mentioned did not cover all of the crop/country combinations agreed upon for this study, were uneven in terms of approach and rigor, and did not analyze systematically all of the promising interventions—technological, financial, organizational, and behavioral. Hence the need for this new action research.

In order to address the questions posed above, based on prior contacts, on-line searching and suggestions from local staff, during the latter part of March seven country teams identified a representative set of key informants within their focus country, who would be asked to participate in purposive one-on-one interviews. Initial interviewees were asked in turn to recommend others, in order to generate a cascade effect that rapidly penetrated the relevant stakeholder networks.

Key informants included individual experts, leading practitioners, heads of producer organizations or industry associations, academic researchers, policy-makers, and other decision-makers relevant to PHL. Since field time was limited to about one month, and the intent was not to conduct a comprehensive survey, the teams assigned to each country did their best to contact and meet with all stakeholder categories of relevance, but a limited number of people within each one. There was no predetermined sample size because the countries varied greatly, as did the crops of interest.

Those who stood out by their responses, as well as others whose voice seemed to matter, were assembled mid-way into the field effort for an expert/stakeholder focus group meeting. These were one-and-a-half to two-day events in urban or semi-urban areas near production areas. Generally presentations and discussions dominated the first day, while working groups by theme and commodity dominated the second day.

By bringing together localized information about the extent and causes of the losses, current best practices and openness to alternatives, as well as potential cost-effectiveness and willingness to pay, the study teams were then able to identify promising interventions for each hotspot in the supply chain. These were prioritized based on the extent of loss, potential for mitigation, and likely return on investment in terms of quantity saved, value improvement, or qualitative factors. As directed, particular attention was given to opportunities arising from each in terms of increased job creation and employment, both on- and off-farm.

Prioritized strategies and interventions were then evaluated in terms of innovation (i.e. what is new or different?), scale (i.e. what opportunities exist for greater adoption and broader impact?), and risk (i.e. what are possible unintended consequences?).

As noted earlier, interventions were examined from four distinct angles:

Do they provide **access** for smallholder farmers to promising solutions and markets?
Are the solutions **affordable** to smallholder farmers?
What is the best way to ensure **adoption** and proper use of the solutions?
How can stakeholder awareness be best achieved?

Gender considerations cut across all four optics, but especially the third and fourth

The study team also considered the current role and potential impact of farmer-based organizations in terms of PHL reduction. Where constructive roles for such organizations were found, recommendations for strategies or interventions by these organizations to assist smallholder farmers to reduce PHL were developed.

Finally, within and across countries, preferred strategies to reduce PHL were formulated, nuanced whenever appropriate according to type of intervention, country, cropping system, and geographic area (including areas served by rapidly accelerating infrastructure and market access versus more remote areas). The main concerns used to prioritize strategies were: innovation (what is new or different?), scale (what opportunities exist for greater adoption and broader impact?), and risk (what are some possible unintended consequences?).

2. Points of Departure

2.1 Conventional Wisdom in the PHL field

This effort builds upon a previously developed body of knowledge that includes analytical work carried out in the 1970s and 1980s (especially the FAO and the Tropical Stored Products Institute), applied research done in the 1980s and 1990s by development organizations and national governments (such as India), and several more recent donor-funded programs of note, especially APHLIS and "Missing Food". Before getting into new findings, it is important to acknowledge what was already known and widely accepted.

One thread that flows through most prior work is recognition that **PHL is a systemic challenge**. It permeates the entire agrifood system globally, and spans plant, animal, and aquatic species. Although PHL is often addressed by targeting specific value/supply chains of particular interest, those chains are often interconnected in myriad ways within the larger agricultural system. For example, maize is not only used for fresh consumption but also for animal and fish feed, and it has multiple industrial applications as well (e.g. starch, high fructose corn syrup, ethanol, etc).

Another thread is acknowledgement that **PHL is caused or influenced by many different contributing factors, which are ever changing and which interact with each other**. Some factors (such as farm management decisions) are controllable, others such as pest and disease pressure can be managed to some degree, while factors such as weather can only be dealt with through a mixture of resilience and coping strategies such as protective structures and diversification.

There is also a consensus within the community of practice (CoP) that **PHL varies greatly by context**, especially agro-ecology, product choice, the production system employed, the characteristics of the source and selling areas, and prevailing conditions in the markets of interest. Ideally each commodity system should be considered separately, yet there are similarities within the perishable versus non-perishable rubrics, and more still within major categories such as coarse grains, grain legumes, or roots and tubers.

The CoP also agrees that **PHL can be reduced at many different intervention points and in many different ways.** One approach is to first select the most economically important value/supply chains, estimate the range of losses at each stage, and then select the most promising interventions for the "hotspots" of greatest concern. Another approach is to identify stages of greatest importance (e.g. drying) for related commodities of interest (e.g. cereals), and then to concentrate on technologies that perform that function best. A third is to focus on the economic actors of interest (i.e. smallholders and women in this case), then develop a "human-centered" strategy that will enhance awareness, interest, capacity to take action, and sustainable behavior change. A fourth approach is to improve the enabling environment, not just policies and regulations but also incentives and disincentives, in the hope that a better supply response can be stimulated. This last approach is increasingly bundled with alliances with market-makers such as MNCs, retailers, processors, input and service providers, sometimes even middlemen. In its field work, the study team kept all of these approaches in mind, not prejudging or preselecting any of them.

2.2 Categories of Post-harvest Loss

Discussions and work around PHL tend to focus on volume losses, failing to recognize that there are other types that matter. This study considered the following categories of loss.

Quantitative

Losses in the weight of harvested crops—measured as dry matter in cereals and other relatively non-perishable crops--harder to define with fresh produce--are the most commonly perceived form of PHL. Not surprisingly, mitigation efforts tend to be primarily focused improved harvesting, drying and storage techniques.

Qualitative

Qualitative losses occur when crops (a) lose quality or condition as perceived by the marketplace, (b) suffer degradation in nutrient content, (c) have less bioavailability, or (d) become entirely unfit for human consumption due to decay, contamination, or adulteration. For Africa, qualitative loss associated with aflatoxin contamination is a particular concern for maize, peanuts, cassava, rice after harvest, and several dozen more susceptible crops. Perishable products generally are susceptible to loss in condition associated with fungal infection, micro-bacteriological contamination, or inappropriate pesticide usage.

Financial

Financial losses occur primarily when potential sales revenue is not received due to either volume or value loss or both, and secondarily when additional costs (such as product withdrawal and destruction) are incurred because of PHL issues. The proximate causes may vary: forced sales at low harvest-glut prices in order to avert quantity or quality PHL during storage, absence of market liquidity, insufficient transportation and storage alternatives, limited access to off-farm warehousing opportunities that offer cash advances pending final sales, non-conformity to required standards, or food safety questions.

Economic

Economic losses (i.e. costs to the general public) may arise from the closing of certain markets (or inability to gain initial admissibility) because of inability to meet regulatory or market requirements. Spillover effects on human, animal or plant health caused by unsafe products or processes represent another source of economic loss. Of particular concern to Africa, for example, is the economic loss caused by aflatoxin-contaminated food and feed.

2.3 Major Determinants of Pre-harvest, Harvest and Post-harvest Losses

As the saying goes, “you reap what you sow”. Many decisions and actions taken in the field long before harvest have lingering postharvest effects. Generally speaking, rainfed production systems entail more PHL than systems that feature good irrigation and drainage. Although selection of improved germplasm may raise marketable yields and produce a more uniform and well-timed harvest, some improved varieties are actually less resistant to pests and disease, both in the field and during storage. For some crops, planting density is a factor that affects not just gross yields but the extent of damage from pests or disease. The timing of planting may also matter, especially when very dry or very wet conditions are likely to occur at critical moments in the plant’s life cycle.

Harvest timing can be a major explanatory factor as well, especially when mixed seeds are used or when maturities are inappropriate for local conditions and rainfall patterns. Although each crop has its own life cycle and therefore physiological maturity, the field work that we did here confirmed that harvest does not always occur precisely at the point of maturity. For climacteric crops that continue to mature after harvest, such as tomatoes, the best point of harvest may actually be before maturity, because the product is less susceptible to bruising and must be allowed to ripen further during transit to the marketplace. Even when that is not an issue, other considerations such as providing support to other crops (e.g. maize stalks to support beans), the lack of storage (e.g. maize or peanuts), or high relative humidity that retards field or patio drying may cause a delay in actual harvest.

The actual tools used for harvesting can also be problematic, as the fieldwork on cassava, teff, and sesame demonstrated. Hand harvesting versus mechanical harvesting can make a significant difference in terms of losses, although sometimes offset by great efficiency and less labor needed.

The same applies, of course, to tools or techniques used for threshing, such as stomping on the product or beating it with a stick, and to equipment used for later transformation, such as oil expellers or hammer mills.

Lastly, the person(s) possessing control over the harvest also matter. Growers of tomatoes for processing in Senegal complained that the processing facility's practice of buying entire fields and directly handling the harvest led to greater losses than would have occurred if farmers retained full control.

2.4 Supply and Demand Dimensions of the PHL Challenge

Supply-side Issues

Much of the attention paid to date to identifying and mitigating post-harvest losses, especially as they affect smallholder farmers, has been focused on losses associated with the technologies and practices employed by that same interest group. Indeed, the fieldwork did confirm some lack of awareness spread across all country and commodity combinations, but not with respect to the fact that losses are occurring. While they could usually pinpoint the hot spots of greatest concern, they could not necessarily quantify the losses nor trace them back to root causes. Most farmers did not clearly distinguish between volume and value losses.

On the other hand, our fieldwork confirmed the notion that farmers nearly always do the best they can with limited resources and in difficult environments. Willingness and capacity to act are not just a function of awareness but also access to physical, technical and financial resources necessary to take appropriate action. The lack of family assets, low annual incomes associated with small landholdings and low productivity in farming, the seasonality of cash flow, and competing demands on scarce cash to meet household needs all represent real barriers to taking steps to mitigate PHL. And for women, child care duties, the need to haul water or find firewood, care for sick family members, meal preparation and other non-agricultural duties often mean a shortage of time or energy to try innovations.

Such limitations at the family level are often exacerbated for the village as a whole by distance and time to market, lack of access roads and means of conveyance, absence of proper storage facilities, lack of market information, poor communications, and dependence on a few traders to provide a market and perhaps a little pre-harvest credit.

SHF willingness to adopt PHL mitigation measures, even when they are aware of the losses and have the capacity to act, are frequently conditioned by a high level of risk aversion and a reliance on traditional ways. A thorough understanding of small farmer circumstances and the perceived risks involved with the adoption of mitigation measures is required in order to design and implement successful PHL mitigation programs. Adherence to traditional ways is generally no more than the manifestation of a small farmer's risk aversion to unproven new ways to manage problems which may not be well understood or even apparent.

In sum, our research found seven factors that have the greatest impact on smallholder adoption decisions:

- **Awareness:** SHFs must be aware of not only the existence of PHL, but of its magnitude. SHFs will be unable to assess the benefits of PHL mitigation solutions if they are unaware of either the level of losses currently being incurred or the amount by which these losses might be reduced through mitigation activities.
- **Cost effectiveness:** Solutions must reduce or halt pre- and/or post-harvest losses more effectively than SHFs' current practice at a cost, including imputed labor costs and the farmer's effective cost of capital when capital investments are required, as well as costs associated with the acquisition of technologies, supplies, and/or maintenance, which is lower than the risk-adjusted perceived value of the benefit.
- **Risk management:** In order to reduce the perceived risk of adoption, solutions should not involve a radical departure from current or traditional practices, but rather an adaptation of traditional practices.
- **Reliability and resilience:** Solutions must be perceived not to rely on continued subsidies or support from the government or third parties, and must be able to withstand changes in weather patterns, market conditions, government policies or other factors beyond the control of the small producer.
- **Size of investment:** Solutions must not presuppose the availability of investment capital nor the willingness of SHF's to incur debt. SHFs demonstrate increasing degrees of investment risk aversion as the magnitude of the downside risk increases.
- **Market acceptance:** Solutions must not reduce the marketability of the product by altering the quality and consistency of supply, reducing their regulatory compliance, or increasing their cost to buyers.
- **Gender roles and requirements:** In order for a solution to be adopted, it must be fully understood by both men and women, and meet gender-specific adoption criteria which may be different between the sexes.

Demand-side Issues and Solutions

Less well understood are the implications of market demand on PHL experienced by smallholder farmers. For many subsistence farmers producing a mix of non-tradable products for own consumption plus small volumes of saleable cereals, groundnuts, teff, or sesame, the only available marketing channel may be a few local traders, who themselves may sell to other traders and market middle men or ladies. In such cases, quality, condition and certainly food safety and other intangibles may have little effect on the prices received. At another extreme, for larger farmers who mainly grow for the marketplace, increasingly they must deal with more demanding buyers who seek quality and consistency of supply of products that are produced responsibly, comply with regulatory standards, meet market requirements and are delivered at a reasonable cost. In the middle one finds famers with some marketable surplus, which perhaps interests niche buyers, such as a tomato processing plant that the team visited in Senegal.

Nearly all farmers aspire to grow and sell more to the marketplace, to gain more leverage with buyers, to be able to aspire to and receive price premiums, to have a steadier price, and in the process raise family incomes and improve food security. Yet as a general rule the smaller and more distant the farm unit and the less differentiated the product, the less empowered is the SHF and the more precarious is the livelihood. Small producers are frequently too far removed from buyers to understand their requirements, and often lack the capacity to interpret and respond to market signals concerning volumes needed, specifications that must be met, and price levels. Unless SHFs become part of a larger unit such as an FBO or cooperative, they will remain subject to the whims of volume-driven market intermediaries who may be unwilling or unable to provide incentives such as stable sourcing arrangements, more attractive terms, sharing of risks, or better application of grades and standards.

Arguably the single most successful form of value chain integration involves the development or strengthening of farmer-based organizations that are able to carry out key collection, aggregation, and post-harvest handling activities such as grading, packing, storing and/or processing, effectively linking SHFs with the market and ensuring that the benefits of these activities accrue to the producers rather than value chain intermediaries or other participants.

Yet for such producer organizations to prosper, they also need to get closer to the market-makers, which include supermarket chains, food service purveyors, food processors, animal and fish feed manufacturers and for some crops, exporters. Improving market linkages from the market backwards is just as important as improving marketable supply. However, establishing such linkages, and causing them to have positive effects in terms of PHL reduction, requires good understanding of modern sourcing practices as well as hard work on the part of supplier leaders, procurement managers and often a development change agent such as AGRA. Of particular importance is the alignment of objectives, a recognition of mutual dependence, establishment of trust, formulation of a realistic buy-sell program, and good communications.

3. Findings

The findings of this investigation are presented in this Volume One in summary form, organized into high-level learnings with resulting recommendations, issues and challenges that straddled countries, and key value chain intervention points as well as associated solutions.

Volume Two contains country-specific information, as well as answers to the many questions posed in the terms of reference. Full country-level matrices of intervention points, challenges and solutions are also provided.

By design the voice of SHFs comes out most strongly in the second volume.

3.1 High Level Findings and Associated Recommendations

1) Although the RF/Agra learning program speaks of "waste and spoilage", that phrase proved very difficult to use in field situations for multiple reasons: (a) most people are not familiar with it; (b) it is hard to translate; (c) the "waste" portion tends to make people think of solid waste, from packaging for example; (d) "spoilage" is most commonly applied to perishables rather than more shelf stable products such as cereal grains; (e) "spoilage" does not really apply when losses in volume occur because (say) pests consume part of the available volume or it simply dehydrates; (f) value loss can occur simply because of timing issues in volatile markets; and (g) other major actors in this field such as BMGF and SaveFood are using different terms. *We recommend sticking with "post-harvest loss", but perhaps qualifying it to focus on food (as opposed to feed, fiber, or industrial raw materials).*

2) On the other hand, even the phrase "post-harvest loss" needs proper interpretation. Prior to harvest, losses may be caused by many different actions, including but not limited to choice of production system, selection of variety and planting materials, timing and method of planting, cultural practices, pest and disease management. During harvest and preparation for sale or storage, losses can be affected by method of harvesting, winnowing, threshing and drying. Afterward, losses that flow back to the farmer may be caused by choice of handling and storage methods, product form/presentation, packaging and packing, loading patterns in conveyance devises, the destination markets chosen, transport methods used, use of cold chain or not, and even supply and demand conditions at the processor or retailer level. *If the term PHL is to be used by AGRA and RF, we suggest that it be interpreted broadly rather than narrowly, with actual harvest the pivot point only.*

3) Although the losses most discussed by farmers and development folk alike tend to be quantitative, i.e. losses in edible or saleable volume, there are other type of loss (qualitative, financial, or economic) that matter as much or more in terms of farmer incomes and ultimate food security. Since all losses do not move together, criteria need to be parsed and impacts disaggregated. *We recommend that AGRA and RF discuss and agree on their preferred criteria, which at a minimum should be volume and value.*

4) There is a hierarchy of quality considerations applicable to each agrifood products, but the specifics vary with the intended use, end-market, and market conditions. Even purely local sales start with product identity, often cover type and variety, and are predicated on basic expectations

regarding lack of adulteration, filth and other foreign matter, organoleptic characteristics, percentage of defects, and absence of contamination that could threaten health. At the other extreme, highly demanding markets require not only compliance with official grades and standards, but also conformity to the commercial specifications of particular buyers. *In its PHL reduction program, we recommend that AGRA be careful to segment the markets of interest, and take associated public and private standards into account when defining losses to be reduced.*

5) Although official grades and standards are supposedly fixed and objective, market realities are such that their enforcement may tighten or loosen depending on whether there is overabundance or scarcity of product. The same applies to the commercial requirements imposed privately by buyers, which show great variation. Initial acceptance or rejection of a shipment, and then the price a given load fetches, are what most affect SHF income. *We recommend that AGRA and RF take a market-led approach in which market acceptance and pricing are treated as the ultimate indicators of value (hence losses as well).*

6) Most smallholder farmers interviewed are well aware of the main PHL problems that affect the marketable volume or perceived quality of their crops, have a reasonably good grasp of how differences in quantity or quality combine to affect prices received, and have concrete ideas regarding preventive or mitigative measures that they would like to implement. On the other hand, rarely can smallholder farmers separate quantity and quality effects (which interact). They also lack precise estimates of how much is lost at each step in the supply chain, and therefore have trouble evaluating potential returns. At a higher level, development organizations and governments also have trouble making decisions regarding alternative investments, and then evaluating progress, both for lack of good data. *For those reasons we recommend that AGRA and RF support continuing efforts by BMGF and others to improve metrics and measurement systems.*

7) The time and place in which losses become evident may not coincide with where and when the main factors that led to the loss may have been present. For example, if bananas are picked too late, they tend to be softer, which can exacerbate the effects of mechanical bruising that occurs later when they are packed or shipped. If onions are not allowed to cure, they tend to rot enroute to market. *We suggest that AGRA and RF decide whether they want to focus on effects, on causes, or both.*

8) The existence of loss and its appreciation by different actors are not synonymous. When the harvest is so abundant that there is sufficient surplus to feed human consumables to barnyard animals, SHFs may perceive that as a benefit rather than a loss, because their animals will fatten up and provide more sustenance in the future. *We suggest that AGRA and RF be guided not only by objectively verifiable loss but also the perception of losses, and perhaps reconsider the idea that any diversion of food that could have been consumed directly and in fresh form by humans be treated as a loss.* Neither the farmers themselves, nor most agricultural economists, would agree.

9) The use of Good Agricultural Practices is just as important to PHL prevention as it is to productivity enhancement. Whether the proper variety is chosen, how soil fertility is maintained, how water is managed, and especially how weeds, pests and diseases are controlled, all have an effect on PHL. What GAP means however, does vary with the crop and context, and unfortunately most extension messaging does not include enough attention to eventual impacts on

PHL. *As AGRA designs and scales up PHL-oriented programs, we urge due consideration of GAP*.

10) Based on results of the field work, the single most important impediment to smallholder adoption of PHL innovation is quite simply the lack of wealth and limited annual income that characterizes SHFs, especially when they are at the subsistence level. While farmers would greatly prefer not to sell their produce at the moment of peak harvest when prices are low, knowing they will have to buy the same kind of product back later when prices are much higher, unfortunately they often the means to store product, and MUST sell prematurely to pay school fees and satisfy other immediate cash needs. *While making farming more profitable and stimulating non-farm rural enterprise may be the preferred longer term solutions, in the short run AGRA and RF may be able to pave the way for greater adoption of PHL innovations by finding creative ways to bridge the financial gap and simultaneously increasing local storage capacity*.

11) SHF adoption of PHL mitigation measures is driven primarily by the perceived effectiveness of the proposed measure in the eyes of the farmer, who tends to focus on clearly identifiable problems such as bruchids in pulses, the large grain borer for maize, shattering in sesame, overripeness in tomatoes, etc. *We recommend that AGRA and RF support participatory rural assessment as a means of validating with local stakeholders the targeting of hot spots along the supply chain, and then focus attention on interventions that deal simply and directly with such high profile and tangible challenges*.

12) In assessing the desirability of PHL solutions, SHFs also take greatly into account the initial out-of-pocket outlay that adoption would imply, and tend to shy away from high upfront expenditures even if there is proof that the intervention will pay off over time. *For interventions that really do work, yet require high outlays, we recommend that AGRA and RF support innovative financing solutions such as buyer or equipment supplier credit that will ameliorate this barrier to adoption*.

13) PHL mitigation measures frequently involve men and women differently (sometimes children as well), and may impose untenable burdens of time and effort on one cohort versus the other. Just as this is a part of the SHF calculus when considering adoption of an innovation, *gender-specific impacts need to be an integral part of the analysis done by AGRA and RF as they identify the highest priority interventions that can be taken to scale.* It is important to keep in mind, however, that even when women participate in assessment, sensitization, and capacity-building activities for PHL specifically and agriculture in general, in many cultures they have limited power to make decisions on how and where to spend money.

14) Uncertainty regarding efficacy and potential payoff from PHL interventions is a major impediment to adoption by smallholders. No matter which interventions are selected, *AGRA and RF should build into the rollout and scaling up process significant effort aimed at local validation via on-farm demonstration, especially with lead farmer, and often in collaboration with seed, agrochemical or equipment suppliers,*

15) Raising awareness and building capacity are interlinked. *We recommend that RF and AGRA support not just proven behavioral change communications and social marketing techniques, but also Farmer Field Schools. .*

16) While SHFs themselves can and should identify tangible and localized PHL impacts, they do not have the knowledge, means of testing and perspective necessary to identify intangible impacts or unforeseen externalities that matter for economic development more broadly. Examples include inappropriate use of pesticides such as malathion in tomatoes in Senegal and DDT in teff in Ethiopia, as well as inadequate management of Aspergillus/aflatoxin in maize or groundnuts all over the Continent. *Before recommending interventions that may have secondary effects on human or animal health or the environment, AGRA and RF should anticipate and guard against such knock-on effects.*

17) SHFs often do not have sufficient information about, nor understanding of, changes in the agrifood marketing system that present new challenges to effective participation as suppliers and/or opportunities to enhance income through postharvest handling improvements that may make it possible to target better market windows, niches, or consumer trends by changing variety, advancing or delaying harvest, engaging in basic culling/grading/sorting, doing minimal processing, or otherwise adding value. *AGRA and RF should seek not only loss mitigation but also revenue enhancing measures based on proper postharvest practices.*

18) Significant PHL that undermines smallholder income can be attributed to a lack of effective integration in value chains. SHF crop production is often ill-timed and lumpy due to dependence on rainfed agriculture, lack of availability of planting materials with more predictable (and either shorter or longer) production cycles, and the inability to manipulate harvest maturity through cultural practices such as top cutting and pruning (e.g. for mangoes) or additives such as the growth hormone gibberellic acid (e.g. for berries). Once the harvest occurs, the absence of adequate storage leaves product exposed to dust, rain, pests and disease. The lack of packing sheds and collection centers prevents effective culling, grading, sorting, fumigation, cooling, storage, packing and packaging. Taken together, these deficiencies translate into low value-added and weak leverage in value chains, which in turn means lower net returns. *SHF empowerment—via innovation, access to finance and productive assets, as well as closer and stronger relationships with leading buyers--should be a major theme in future RF/AGRA work in the PHL arena.*

19) Since business opportunities for SHFs exist in both the more demanding export, processor, and urban markets and in less demanding popular markets., *we recommend that AGRA and RF take a dual approach: on the one hand, helping client SHF groups to better respond to the emerging standards and expectations of higher value markets where they may be accessible, and on the other hand using institutional "muscle" to raise the bar in terms of quality in traditional markets.*

20) Since high return agriculture depends on economies of scale, it is also critical to establish or strengthen farmer-based organizations, producer cooperatives and other mechanisms for collective action. Once organized, such groups can facilitate aggregation, shared cold or dry storage, forward integration, negotiation and management of supply contracts, participation in outsourcing schemes, better access to market information, better access to credit and inputs on favorable terms, and higher utilization of technological innovations. *We recommend that AGRA and RF provide matching grant support to development intermediaries capable of stimulating and nurturing private agricultural organizations that increase SHF leverage in better value chains.*

21) Farmer-based organizations empower SHFs to move from a passive acceptance of PHL as a natural and unavoidable aspect of farming (i.e. “nature taking its share”, as we heard in the fieldwork) to an active role in PHL mitigation by addressing demand side issues. However, since agrifood marketing is increasingly governed by buyer-driven value chains, especially for high value products and for higher end markets, it is also important to help supermarket procurement organizations and the raw material supply managers for processing enterprises to more effectively reach out to a greater number of SHF producers and their FBOs. *AGRA and RF can and should work with interested market-making firms to design, kick-start. and then implement more inclusive outgrower schemes and contract farming arrangements that will better distribute rewards and risks, stimulate a stronger and more appropriate supply response, facilitate buyer financing for production credit and the acquisition of productive assets, and in general help SHFs migrate from the role of spot sellers toward preferred supplier status*. Better PHL reduction is a critical part of that process.

22) As noted later in this report and cited in the country annexes, most supply-side PHL issues may be addressed by SHFs with relatively simple and low cost solutions involving improved cultural, harvesting, drying and on-farm storage practices. While there are some particularly promising new solutions that involve new materials, equipment, testing devices, or approaches, the fieldwork found no silver bullets, and the field team left more convinced than ever that what is needed is selective application on a much larger scale of what has already proven effective in rural Africa. *We recommend that AGRA and RF move as quickly as possible beyond the stage of searching for solutions to specific losses of interest, select a limited set of them to concentrate on, and then invest in perfecting delivery mechanisms that can reach much greater numbers at a reasonable cost, ideally in a market-sensitive manner.*

23) While focusing on promising solutions to well recognized hotspots of loss, and then scaling them up, will have tangible impact in the lives of SHFs and their families, system-wide problems remain. RF and Agra are well-positioned to address some of those systemic challenges directly and others indirectly with like-minded development partners. Notable examples include political will, levels of funding, strengthening of the CoP, and creation of a shared knowledge base. In our view it is critical *that RF and AGRA play a leadership and catalytic role in bringing interested players together into a coalition with a reasonably coherent long-term and global vision.* Perhaps it could be built around the transformative ideas presented by Abt Associates at the mid-April convening of learning partners held in Nairobi, which are repeated in the text box below.

Transformative Ideas for Post-harvest Loss Reduction at Scale

1) **Join forces with other funding entities to reach agreement on fundamentals**
2) **Support creation and maintenance of a comprehensive, user-friendly knowledge platform, starting with SSA**
3) **Invest methodically and over the long term in human, institutional and social capital for PHL**
4) **Adapt Risk Assessment principles/practices to PHL and promulgate widely the idea of Loss Assessment at Critical Control points**
5) **Help move the development community from situation analysis toward scalable prevention and mitigation**
6) **Develop and promulgate investment support systems for donors, governments, NGOs**
7) **Build partnerships with market-makers to improve access, incentives, and sourcing relationships**
8) **Develop and promulgate decision support tools for supply chain actors**
9) **Fund adaptive research to discover how best to link predictive modelling of biotic stresses to crop management and PHL reduction**
10) **Support adaptive research on ways to adapt social marketing and behavioral change techniques to the PHL challenge**
11) **Use Sub-Saharan Africa as test bed and proving ground for PHL-related innovation**
12) **Join forces with the emerging mycotoxin management movement**

3.2 Prioritized Smallholder Issues, Challenges, Skills and Capabilities and Key Value Chain Intervention Points

Our field work on this PHL investigation employed a value chain approach to identify the specific challenges faced by smallholder farmers with respect to PHL losses as well as potential mitigation measures. At each hot spot where significant PHL issues were noted, we explored the apparent causal factors, identified the most promising solutions, and then weighed them against SHF capacity and skills. Detailed results are given by country in Volume Two.

Some commonalities across crops at each stage of the supply chain are presented below.

- **Varietal selection**, although a production issue in the mind of most, was perceived by farmers and experts alike as critical to PHL as well as productivity. For example, certain improved **sesame** cultivars are more or less prone to shattering on harvest; the main **cassava** types have differential storage properties in-ground from the point of maturity (drier types destined for industrial applications keep longer, but are more readily prone to lignify, whereas wetter 'fresh' types rot much more easily, particularly in humid soils); **tomato** varieties are also divided into wetter types, such as those of northern Ghana (destined for cooking and local market sales), and the drier, 'fleshy' types such as those imported from Burkina Faso, which are more durable and therefore more readily transportable from production zones to urban markets with minimal losses.
- **Planting methods** can also affect harvest and post-harvest processing (in Ethiopia, sesame that is broadcast planted by hand results in weaker stems that cannot bear mechanized harvest technologies, which is in contrast to line-planting).
- **Timing of planting** can be a strategy to reduce the risks of PHL, as with the staggering of irrigated tomato production to avoid over-abundant supply at times of seasonal peak harvest (this was reported in Senegal, Ghana and Tanzania in particular).
- Proper **weed, pest and disease control** can not only reduce stress and injury to the plant itself, but also reduce the incidence and burden of attack or competition for nutrients and water. For example, clearing away crop residues that are decomposing can deprive the aflatoxin-generating *Aspergillus* mold of a substrate in which it can prosper in between cycles.
- **Timing of harvest** strongly affects PHL, partly because there are seasonal agricultural labor bottlenecks from some country/crop combinations (such maize in Kenya) and partly because of the difficulty of post-harvest storage (e.g. cassava in all countries studied). Diurnal effects of harvest time may also play a role (e.g. it is better to harvest shatter-prone sesame and pulses in the early morning hours, when lower temperatures and higher ambient humidity serve to protect the integrity of harvested pods).
- **Harvest methods** very obviously play a role in PHL, as a function of the multiple factors mentioned above – particularly in the distinction between manual and mechanized harvesting of a variety of crops. Beyond the question of 'man [or woman] versus machine' there are a range of appropriate solutions to mitigate risks of PHL during harvest, such as spreading of plastic sheets between rows of shatter-prone pulses and sesame in Ghana, Ethiopia and Kenya.
- **Drying** of harvested crops is handled by a range of methods, with perhaps the strongest effects on PHL in terms of quality (viz the heaping of freshly harvested groundnut in Senegal, often in contact with soil and therefore the *Aspergillus* spores that lead to aflatoxin); mechanical

(electrical or gas-powered) or solar driers can drastically reduce drying time, which is the critical factor to preserve product quality – but more locally-available measures such as tarpaulins or raised platforms also help to preserve the quality and quantity of harvested crops.

- **On-farm storage** methods are also critical – particularly in terms of air circulation (as well as proper pre-storage drying, in general to a range between 5-10% humidity, depending upon the crop). While a range of 'improved' storage methods are known, they are not always appropriate to a given micro-climate (condensation in metal silos being one example), nor properly used (hermetic storage methods such as zipper-equipped 'cocoons' and plastic 'silos' under development in Kenya) are quite vulnerable to ineffective sealing. Some particularly vigorous and determined insect pests, such as the LGB in Kenya, proved capable of compromising the early ultrahermetic bags.
- **Locally-appropriate storage solutions** should clearly be given first consideration at the household level. Though prone to theft in some modern societal contexts, traditional granaries made from woven materials, mud and thatching can provide optimal aeration for stored grains, and can be rat-proofed and otherwise improved - whereas woven polypropylene bags can both seal in latent humidity, and wick up moisture from the ground if they are not adequately palletized and kept away from mud or masonry walls, as they are typically stored in a house or similar secure structure. Other appropriate storage solutions include double-bagging of grains and pulses, such as cowpea in northeast Ghana (cheaper and comparably effective as compared to the significantly more expensive and generally less available 'triple-bagging' method known as PICS), and 'zero energy' coolers made from mud and thatch for preserving locally-grown tomato in central Ghana.
- **Collective arrangements** for various post-harvest handling activities including sorting, packing and marketing of perishable or drying and storage of non-perishable products destined for market such as the Ethiopian Commodity Exchange (ECX) as well as producer-owned cooperatives and unions for sesame offer important benefits to SHFs where available, but are often more difficult to manage so as to ensure transparency and retain the confidence and trust of small producers.
- As mentioned above, **technical training** is an essential component of effective diffusion and adoption of PHL-reducing technologies for smallholder farmers. One notable example is a seemingly promising molded plastic household granary, recently developed in Kenya – but obtaining a proper seal is tricky, and does require an investment in technical training for effective use.
- Beyond the choice of technology, **storage management** solutions are equally if not more important – consisting of such tried-but-true tactics as regular inspection, sorting and re-drying of stored produce, with judicious use of appropriate agro-chemicals to keep pest populations low. Storage hygiene is critical, and cannot be over-emphasized by iterative technical training; other management skills may include basic business practices as well as product quality control, quality assurance and contractual practice.
- On its way to market, **transport** is often a weak link along some value chains; as a case in point, the 'market queens' of Ghana own the crates in which tomato is transported, and the crates they use are not at all well-suited to product preservation. Heaping of tomato atop such crates leads to skimming of product by transporters as well as losses accrued by crushing and waste of tomato in transport. Another notable trade-off presents itself in the timing of transport: in Ghana, tomato

transporters formerly drove by night for reduced temperatures, but this resulted in an unacceptable frequency of road accidents – they now drive exclusively during daylight hours.

- Particularly for more perishable crops (such as cassava and tomato), **artisanal or industrial food processing** can be a means of reducing losses (resulting in a more stable product, such as cassava chips or flour) and/or a means of adding value (viz tapioca, or fermented food products with high regional market demand, such as gari and attieke across West Africa). However, processed foods may be more liable to enforcement of national product quality standards, which can serve as barriers to commercialization for smallholder farmers in particular. Despite the ubiquity of Kenya-manufactured (Kenylon brand) stewed and pureed tomato, the tomato is canned but not grown in Kenya, due to the strict traceability requirements of the Kenya Bureau of Standards, coupled with pesticide use regulations.

3.3 Cross-cutting Country-level Findings

Our research and analysis led to a number of cross-cutting country-level findings:

- Both national governments and international donor-funded programs continue to place primary emphasis on improved pre-farmgate productivity, with little attention given to improvements along the rest of the value chain that would enhance small producer income and rural livelihoods;
- National and donor-funded PHL programs are primarily focused in mitigation rather than measurement despite the need of SHFs to understand the magnitude of their losses as a precondition to the adoption of mitigation measures;
- Agricultural extensionists as well as other country-level agricultural development practitioners are increasingly impatient with the many analytical studies, workshops and focus group discussions occurring around PHL reduction, and an expressed desire for more tangible action;
- There is recognition that solutions need to be customized by crop, agro-ecology, weather, type of producer and production system, and the intended market. “One size does not fit all” and there is a need for increased capacity at the local level to customize and implement PHL locally appropriate solutions;
- There is a need for external technical and financial support but a growing frustration with donor as opposed to local leadership based on on-the-ground knowledge;
- PHL is not yet a major thrust in national poverty reduction strategy papers (PRSPs), food security plans or agricultural development strategies;
- Most countries have very small PHL units within their Ministries of Agriculture, one or two donor assisted projects and several relevant agricultural development or value chain projects on which to build PHL programs with greater impact.

3.4 Cross-cutting Findings by Crop Value Chain

3.4.1 Roots/Tubers (Cassava)

PHL in the cassava value chain was analyzed in Senegal, Ghana, Nigeria and Mozambique.

Issues/Challenges

On Farm: Most of the challenges facing SHFs in all four countries flow from the characteristics of the cassava plant itself. The “drier” varieties that are more appropriate for industrial use keep longer but are more readily prone to lignify, whereas the wetter “fresh” types that are preferred for human consumption rot much more easily, particularly in humid soils.

After reaching physiological maturity, cassava may remain in the ground for up to 12-14 weeks with relatively little deterioration in volume or quality. If left in the ground beyond 14 weeks, or if the ground becomes humid (due to the onset of the rainy season), this may result in fibrous (hardened) tuber and rot.

Because cassava is rainfed and generally planted to take advantage of the rainy season, it reaches maturity during the dry season when soils are hardened, resulting in greater difficulty in uprooting the tubers and higher losses due to breakage. SHFs spoke of the need for better implements.

Once harvested, natural deterioration begins within 2-3 days resulting in an immediate loss of market value and rendering the fresh product unfit for human consumption within a week to ten days. Product deterioration may be slowed or halted by proper drying, preservation or processing.

For SHFs in all four countries who use cassava primarily as a food crop for home consumption, “*in situ*” storage (i.e., leaving the cassava in the ground) until the cassava is needed for home consumption minimizes PHL and is generally perceived as preferable to post-harvest storage.

However, a growing proportion of SHF cassava production is destined for sale (especially in growing areas near larger towns and cities). Since farmers plant at the same time because cultivation is rainfed and seasonal, sales at harvest sometimes lead to gluts in the market, causing some farmers to postpone harvest of their tubers while waiting for periods of scarcity and higher prices. This may result in losses if harvesting is delayed too long or if there is unexpected rainfall. As discussed below, the market for fresh cassava is also limited in most areas due to the risk of deterioration in-transit or in storage prior to processing or retail sale and small producers may discover that they are unable to sell their freshly harvested cassava at any price.

In order to avoid losses associated with *in situ* “storage,” farmers may harvest their cassava and attempt to sell it fresh, or store and/or process it following harvest. Current practices observed in the countries studied include various forms of post-harvest storage with differing degrees of effectiveness in delaying the natural deterioration of freshly harvested cassava. (These practices are discussed in detail in the following section on “intervention points.”)

Small cassava producers are therefore left to choose between the following four alternatives for selling their cassava:

1) Storing the cassava in situ until market prices improve but risking in-ground PHL;
2) Harvesting the cassava at its physiological maturity and selling recently harvested cassava at seasonally low prices (or not at all if buyer absorption capacity is saturated);
3) Harvesting it when mature and storing it on-farm and risking significant PHL due to the cassava’s natural post-harvest deterioration, or

4) Processing recently-harvested cassava into chips, flour or wet-mash, which may be stored longer with less physical or quality loss, and sold more easily, but at a discount as compared with fresh cassava.

Off-farm: In addition to the on-farm challenges described above, SHFs are affected by off-farm PHL which result in low farm-gate prices and/or lack of market access, especially for fresh cassava.

Due again to the extreme perishability of fresh cassava, as well as to generally poor transportation infrastructure, fresh cassava is subject to deterioration en route to the first off-farm receiver, and is subject to further deterioration during storage and handling by traders and processors who do not take adequate precautions regarding packing, loading, and off-loading of trucks, or storage prior to processing. While such practices lead to PHL and a loss of value to traders and processors, they also result in lower farm-gate prices to producers since traders and processors must discount the cost of spoiled products in prices paid to producers. They also frequently result in the inability of producers to find markets for their fresh cassava due to limits to the transportation and storage capacity of traders and processors imposed by the perishability of the fresh cassava.

Given these challenges, the primary issue facing SHFs of cassava for sale in all four countries is how to maximize the market value of their product while:

- Avoiding market gluts and associated seasonally low prices;
- Minimizing pre-harvest loss associated with in-ground storage
- Minimizing post-harvest loss due to deterioration of freshly harvested tubers, and
- Minimizing the cost and loss of value of on-farm processing to reduce PHL.

SHFs wishing to sell some or all their cassava into the cassava value chain require PHL solutions that will provide maximum marketing flexibility (i.e. ability to choose when and to whom to sell) by either preserving the qualities of fresh cassava during post-harvest storage, or by minimizing the cost and loss of value due to on-farm processing in order to avoid PHL. Off-farm value chain participants who are able to reduce PHL during transport, storage and processing will also be able to provide improved market access and better farm-gate prices to producers.

Key Intervention Points

We found numerous interventions points in the cassava value chain where one or more solutions exist that address the issues and challenges described in the previous section. While no single solution is appropriate for all SHFs, clearly opportunities exist to share across countries innovations or best practices that have been tested and widely adopted in one country.

Annex 1 presents matrices that flesh out the three key intervention points in each country where solutions appear to have the most potential for reducing PHL to small producers. Below we highlight one particular intervention point in the cassava value chain that offers significant opportunity for maximum benefit in all four countries, along with five solutions or innovations – each currently practiced in one or more of the countries studied – that provide different levels of benefits and costs to SHF. In most cases, the solutions are neither sophisticated nor difficult, and only require that practitioners be made aware of the consequences of their current practice and the advantages of doing things a bit differently.

Cassava Intervention Point: On-farm Drying/Processing

Freshly harvested cassava that is not immediately sold to intermediaries or first receivers due to low prices or lack of market access must be dried and/or processed to avoid rapid quality deterioration.

Solutions

Numerous solutions were observed, all of which offer some benefits to SHFs.

- Storage of fresh cassava in the shade on pallets/raised platforms, covered with fresh shrubs;
- Cutting and air-drying;
- Use of "Low Cost Fresh Cassava storage" methodology (sorting, washing, bagging in plastic, storage on pallets) to extend freshness by 10-14 days;
- Waxing freshly-harvested cassava
- On-farm or community processing of fresh cassava into dry cassava chips/flour (*kokonte*).

Accessibility

The first three solutions require little more than awareness of the consequences of current practices and the benefits of the proposed solution. The solutions do not require capital outlays (other than perhaps the construction of a raised platform for storage), nor additional supplies beyond the purchase of plastic bags.

Waxing freshly harvested cassava is an option now widely used in Central America but not yet in Africa that requires some specialized training as well as some additional expense for the purchase of the wax – which may not be readily accessible in large quantities. Accessibility issues related to waxing could be mitigated through village-based extension and collective purchase of sufficient wax to meet all villagers' needs for a single season.

On-farm processing presents perhaps the greatest opportunity for PHL and improved net income by basically eliminating the perishability of the cassava and increasing its marketability. Traditional forms of on-farm processing are widespread and may be improved through the use of improved drying methods such as solar dryers. Labor saving methods including improved mobile processing units – large vehicles that travel to smallholder farms and process cassava into cakes, then buy the cakes from the farmers – or village-based processing centers (such as FCI's Commercial Village Processing Program) are especially relevant for women who generally bear the brunt of more traditional and labor-intensive methods of on-farm processing. Accessibility issues are greater here, as processing equipment is expensive, generally beyond the reach of an individual small producer, and must be used by many SHFs in order to cover its cost. Accessibility issues may be mitigated only through the creation or strengthening of farmer-based organizations (FBOs) which are able to collectively purchase and operate processing equipment, or enter into contracts with private sector buyers willing to provide on-site processing to SHFs.

Affordability

While waxing will provide insurance against deterioration if cassava is not sold immediately after harvesting, farmers may have difficulty perceiving the benefit if they expect to be able to sell their crop at harvest and at a good price. The benefit of waxing may be more apparent if traders and processors are willing to pay a higher price for waxed cassava in order to reduce their own PHL during transport and storage prior to processing.

Post-harvest processing using traditional processing methods is generally only cost effective when direct sales of fresh cassava are not possible, as may be the case for SHFs located at a distance from local markets and with poor access to transportation. The cost of on-farm processing using traditional methods, especially in terms of the labor requirements of women, may exceed their availability given their multiple responsibilities. Improved drying equipment may contribute to an improved product and possibly higher prices or greater market access, although this would be difficult to demonstrate. Post-harvest processing using mobile processing units or centralized, village-operated processing equipment are more cost effective both in terms of the value of the processed product and in terms of the amount of labor required. Capital costs are, however, significant and can generally only be met by either private sector buyers or by FBOs with access to development financing.

Adoption

Adoption of slightly improved methods to store and dry cassava in order to preserve its quality for up to 14 days and permit greater marketing flexibility is primarily dependent on the degree of awareness by the SHF of the benefits of improved storage methods. As there is little to no downside risk to the adoption of the improved storage methods, as well as little to no significant incremental cost, and the primary purpose is to improve market acceptability, adoption will be primarily a function of awareness, which can be achieved through either local opinion leaders or trusted extensionists.

Adoption of waxing does require significant behavior change and entails additional initial uncertainty as SHFs will not necessarily know or believe that waxing does indeed lengthen the shelf life and improve the value of the freshly harvested cassava. In order to promote adoption, in addition to demonstrating the effectiveness of waxing, SHFs must be convinced that waxing is cost effective, which they will only be able to see in the form of higher prices paid by buyers, indicating market acceptance, to compare with the cost of waxing.

On-farm processing is widespread but perceived as less attractive to the sale of fresh cassava due to both the cost involved (primarily in the form of women's labor) and the prices received for the generally low-value chips, flour or mash. Adoption of either improved forms of on-farm processing (involving solar dryers, etc.) or mechanical processing using either mobile processing units or collective, village-based processing systems, involves significant behavior change and greatly increased perceived risks due to lack of familiarity. Farmers may typically risk processing only a portion of their production using these methods and wait until they are able to experience improved financial returns before fully adopting the innovation. Promoters of such innovations should be willing to wait for several crop cycles before expecting full adoption of the new processing methods.

Gender

The five solutions to reduce PHL at the on-farm drying/processing intervention point have very different gender implications.

The first three solutions – platform, shade drying; cutting and air-drying; and "Low Cost Fresh Cassava Storage" all involve some increase in labor, primarily supplied by women who are generally charged with post-harvest storage, drying and on-farm processing activities while men are generally responsible for field activities. Since adoption decisions regarding each of these methods do not involve either men's labor or cash expenditures, they may be taken by women without the involvement of male partners.

Waxing may actually involve less labor (by women) than the previous three activities, but due to its increased cost and access issues, it may require that men, who traditionally control cash expenditures, participate in the decision to adopt this technology.

A decision to invest in improved drying methods as part of on-farm processing of cassava into chips, flour or mash may be made by male partners in order to increase the market value of the processed cassava product, but will not lessen the labor requirement of women to engage in further on-farm processing activities.

A decision to participate in a buyer-operated mobile processing scheme or in a community-based processing system may represent significant benefits to all household members by increasing the value of the processed cassava product while significantly reducing the amount of household labor involved.

Mechanized on-farm or community-based cassava processing systems represent the innovation at the on-farm drying/processing intervention point with greatest economic and non-economic benefits for small holder households, and especially for women in small holder households. Barriers to adoption are both financial and cultural. Financial barriers may be mitigated through government or donor support, while cultural barriers, which are primarily risk-related, will only be overcome as SHFs are able to experience the benefits.

3.4.2 Beans/Pulses

Post-harvest losses in the bean/pulse value chain were examined in Ghana, Kenya, Tanzania and Mozambique. Although numerous distinct types and species comprise this category, most notably dry beans, pigeon peas, and cow peas, PHL issues and challenges are similar across most bean/pulse crops and countries.

Issues/challenges

Beans and pulses are usually grown in Africa as a secondary crop, frequently intercropped with maize or other primary crops. Climbing beans use the stalks of maize for trellising, and drying/harvesting practices are tied to those employed for maize. Bush beans do not rely on other plants for trellising, but when intercropped they are also affected by the planting, drying and harvesting practices of the companion crop. When intercropped, pulses and beans are generally planted after the other crop has begun to grow, thus tying planting dates to the other crop's calendar.

Due to the physiology of the pulse plant, the following three operations must take place after the pulse plant reaches physiological maturity in order for the final product to be stored for later consumption:

1) The pulse pod must dry out sufficiently to avoid rotting on the stalk and enable the beans to be extracted without damage.

General practice among SHFs is to leave the pods on the stalks in the field after reaching maturity in order to dry, and after a period of field drying, to uproot the entire plant, including the pods, and place them in piles at the edge of the field for further drying. If the particular variety is late maturing or the rainy season is early, pods may rot on the stalk or be unable to dry sufficiently to extract all the beans from the pods without further damage.

2) The pulse pods must be broken open and the beans inside extracted.

Once pods are judged to be sufficiently dry, they are manually threshed by beating the pods with sticks until the inner beans are released. If, as described above, the pods are not sufficiently dry, their beans will not be released. For pods which are sufficiently dry, the rudimentary nature of the threshing process results in many beans which are lost as the "fly out" of the area where the pods are being beaten, or are physically damaged (shattered) due to beating.

3) Finally, the pulses or beans must be thoroughly dried to avoid spoilage during storage.

The general practice is to sun-dry the beans following threshing, although the onset of the rainy season or a lack of sufficient patio space may result in insufficiently-dried beans being bagged and stored for home consumption or sold to intermediaries.

In all four countries studied, SHFs were aware of PHL in the following intervention points and expressed interest in improved practices or technologies that would reduce losses:

<u>Field Drying/Harvesting:</u> Conscious of PHL caused by poor varieties which take longer to mature and lead to a higher risk of spoilage in the field prior to harvesting due to climatic events or pests, SHFs interviewed expressed a desire for shorter cycle varieties which would be able to mature and field dry and harvest before the beginning of the rainy season.

<u>Threshing:</u> SHFs are conscious of the losses due to damaged or lost beans during the threshing process, but are either unaware of or lack access to improved threshing technologies, such as threshing machines developed at Washington State University, or simpler solutions involving plastic tubs or "threshing houses."

<u>Drying:</u> SHFs understand that PHL during storage is frequently caused by inadequate drying of the beans following threshing. Rain and a lack of alternatives to sun drying lead to rot, mold and insect damage during storage.

<u>Storage:</u> SHFs are conscious of losses due to pests and humidity during storage, generally in their houses, but lack knowledge of or access to improved storage methods.

<u>Sale at Low Harvest Prices:</u> In order to avoid storage losses, as well as to obtain needed cash for household needs (including school supplies), farmers frequently sell their crops at harvest when prices are at their seasonal low. Improved storage methods would partially relieve the pressure SHFs feel to sell at harvest time.

Key Intervention Points

Guided by SHFs own identification of key intervention points, we have selected three to discuss here. (Additional intervention points by country are presented in Volume Two)

Bean/Pulse Intervention Point: Field Drying/Harvesting

PHL losses incurred at the field drying/harvesting stage are frequently the result of traditional long-cycle bean/pulse varieties that mature after the rainy season begins and are subject to insect damage, rot and inadequate drying before being harvested.

Additional PHL losses are incurred due to the practice of uprooting the entire bean plant and placing it in piles at the edge of the field, resulting in losses due to contact with humid soils and damaged pods due to rough handling.

Solutions

Shorter-cycle varieties of beans and pulses exist and can be adapted to local conditions by agricultural research organizations and disseminated through farmer-to-farmer networks, agricultural extension systems or agricultural supply dealers.

The use of plastic sheets rather than throwing uprooted plants on the ground will improve drying; care in uprooting entire plants will reduce physical damage to pods.

Accessibility

The principle problem in making shorter-cycle varieties accessible to SHFs is the decision-making process within agricultural research organizations to devote research resources to adapting known varieties to local growing conditions and producing sufficient quantities to distribute to lead farmers. This can be addressed at the research policy-making level by national government agencies or international organizations such as AGRA. Once locally-appropriate short-cycle varieties are released, increased by government agencies and distributed to lead farmers, additional distribution will take place primarily through farmer-to-farmer networks.

The purchase of plastic sheets may present an accessibility problem if they are not readily available locally; collective action by FBOs may facilitate their acquisition. Changes in harvesting methods involve no accessibility issues on SHFs.

Affordability

Short-cycle bean and pulse varieties released through national agricultural research systems and distributed through farmer-to-farmer networks do not impose additional costs on SHFs.

Plastic sheets do involve minor incremental costs, but farmers will easily see the benefits of improved drying and protection from ground humidity as outweighing the relatively small incremental cost.

Care in handling uprooted bean plants to avoid damage to bean pods requires little if any additional labor but will only be practiced if the benefits of doing so are apparent.

Adoption

Adoption of new seed varieties is among the riskiest decisions a farmer makes, especially if the risk of crop failure will result in an acute food shortage for the farmer’s family. For this reason, farm extensionists and/or lead farmers must manage a multi-cycle adoption process involving demonstration plots, farmer field schools, and small test plots by each farmer using only a small portion of his/her field to test the new varieties. Only after farmers experience the results of the new short-cycle varieties themselves under a variety of growing conditions (early rains, prolonged droughts, etc.), will they be willing to fully adopt improved short-cycle varieties.

The adoption of plastic sheets and gentler handling of bean plants during the harvest will depend on farmers’ perception of the costs involved versus benefits to be received. The use of plastic sheets and gentler handling of uprooted plants will pose few adoption problems once farmers become aware of their losses using current practices.

Gender

Given traditional gender roles in which men generally are more involved in field activities including planting and harvesting as well as the purchase of farm supplies and the sale of farm produce, and women generally manage post-harvest handling and storage as well as household consumption, decisions regarding the adoption of short-cycle varieties will be generally made by men but will not have adverse impacts on women.

Decisions regarding the use of plastic sheets require the approval of men who control farm expenditures, but will primarily benefit women who will realize the benefit of this practice. As such, communication regarding the benefits of the use of plastic sheets must be made to both men and women.

As men are primarily involved in uprooting bean plants during the harvesting process, but women are the ones to observe the benefits of gentler handling of the uprooted plants, it will be important for men to be made aware of the losses caused by their rough handling of the bean plants and the damage to the pods which such handling causes.

The adaptation of shorter-cycle beans and pulses to local growing conditions may have a significant impact on the reduction of PHL in beans and pulses as the risk of pods rotting on the stalk or inadequate field drying is reduced. Varietal adaptation requires significant investment in research and may be best achieved through specialized development funding.

Bean/Pulse Intervention Point: Threshing

Current universal SHF practice is to thresh beans and pulses by placing dried pods in a pile on the ground and beating them with sticks to break open the pods and release the beans. In addition to being a very labor intensive process, this practice results in a high percentage of broken or shattered beans as well as lost beans which are scattered beyond the work area due to the impact of the beaters.

Solution

With the exception of a prototype bean thresher produced at Washington State University, there is no knowledge of locally available bean threshers appropriate for small farmers in the countries studied. The design, manufacture and distribution of a simple (possibly hand-powered) bean thresher appropriate for small farmers would represent a solution that would reduce PHL during the threshing process and also save labor (mostly for women).

Accessibility

Threshing machines appropriate for small producers and not currently available, and larger threshers are not accessible to small farmers due to their minimum scale requirements.

Once design and manufactured, threshing machines must be made accessible to SHFs through retail farm supply networks.

Affordability

In order for a small scale bean thresher to be cost-effective for SHFs, its cost must be sufficiently low to be offset by the reduction in threshing PHL and the labor saved. Since household labor is seldom priced – even implicitly – PHL savings alone will be required to demonstrate the cost-effectiveness of the thresher. Depending on the amount of investment required, hand-powered threshers may be within the financial reach of some or most SHFs. More entrepreneurially-minded SHFs may also find value in custom threshing for their neighbors, and justify a higher initial investment by the expected return from custom threshing.

Adoption

Adoption of threshing machines will almost entirely depend on the benefit-cost calculation made by the individual farmer, as well as the farmer's access to capital to make the purchase. Few non-economic barriers to adoption can be envisioned if the SHF perceives the economic benefits to be sufficient to offset the investment cost.

Risk aversion, however, may be a barrier to adoption if the initial investment cost is high or if the amount of PHL reduction to be realized is not well understood.

Mitigation of SHF risk aversion to the purchase of threshing machines might include the quantification of PHL due to traditional threshing.

Gender

As in previous examples, the purchase of a threshing machine (once designed, manufactured and made available locally) will have significant gender implications. Since major farm investment decisions are generally made by men, the decision to invest in a thresher will be primarily made by men. Women, however, are those who will both benefit from the reduced labor requirement, and be better able to appreciate the reduction in PHL due to mechanized threshing. In promoting the adoption of mechanical threshers, it will be important to demonstrate to men the economic value of the reduced PHL in order to facilitate the adoption decision.

Low cost, possibly hand-powered bean threshers are currently unavailable to SHFs in Africa but would represent an important solution to PHL losses with significant gender implications. Governments and donor organizations may wish to support their development.

Bean/Pulse Intervention Point: Farm Level Storage

Across all countries and regions studied, current on-farm storage practice generally involves bagging dried beans/pulses and storing them in SHF houses. When beans/pulses are not thoroughly dried (as is frequently the case), they may be subject to PHL in the form of mold or rot. Stored beans/pulses are also subject to PHL in the form of insect and rodent damage even when appropriately dried.

Solutions

Solutions to on-farm storage issues include both improved drying of harvested and threshed beans, and the use of improved packing materials.

A wide variety of improved drying technologies are available, including conventional and solar-powered dryers, but investment costs and minimum sizes which exceed SHF needs are barriers to adoption. No small-scale drying solutions which are appropriate for SHFs other than variations on sun drying were observed during this study or mentioned by those interviewed.

Improved bagging technologies, including the triple-bagging system developed at Purdue University, and locally available double-bagging methods using a single polythene insert, provide significant advantages in reduced PHL by allowing moisture to escape while protecting beans from insects and rodents.

Accessibility

As mentioned above, no small-scale drying solutions other than variations on sun drying are currently accessible to individual SHFs. Research and development of drying solutions (which may also be appropriate for other crops) should be a priority in a program to reduce PHL due to inadequate drying.

Triple- and double-bagging technology is readily accessible throughout most growing areas, but acquisition costs limit their accessibility to many small holders.

Affordability

As with previously discussed PHL solutions, in order for a SHF to evaluate the benefit-cost relationship of dryers (when they become available) or of triple- or double bagging, some quantification of PHL averted must be made to compare with the cost of the solution. While SHFs are aware of storage-related PHL, they are not necessarily aware of its magnitude nor are they able to estimate its value and compare it to the cost of the PHL solution (drying or bagging). In cases where PHL averted means increased food available for household consumption rather than for commercial sales, even a positive benefit-cost relationship will not imply access to the cash necessary to purchase dryers or improved bags.

While the purchase improved bagging materials must be financed with normal household income, the purchase of improved dryers, when they become available, may require special financing arrangements which might best be provided through government or donor-funded initiatives rather than through high-interest traditional money lenders.

Adoption

For SHFs accustomed to storing beans/pulses in bags inside their homes, the adoption of improved bagging materials will be driven by economic benefit-cost analysis alone, based on SHFs perceptions of the benefits related with the PHL reduction. As discussed above, these perceptions may be ill-founded as there has been little or no effort to quantify PHL losses at the household level. Interventions to assist SHFs in understanding and quantifying their storage-related PHL may be an important element in promoting adoption of improved bagging.

For SHFs who are accustomed to storing beans/pulses in traditional silos or similar permanent structures, the adoption of improved bagging represents a greater behavior change and a break with traditional storage methods which may be perceived as more risky and be more difficult to overcome. In these cases, as in the case of improved varieties, SHFs might be encouraged to test the improved bagging solution with a small portion of their harvest and compare the results. Ponce SHFs become convinced of the benefit of improved bagging technology, they will be more willing to adopt the change.

Improved dryers, when they become available, will also represent a significant break with traditional practice with a high level of associated risk. Both the investment cost and the risk that the technology will not produce the desired benefits will be significant impediments to adoption. Since the installation of dryers cannot be done on a test basis as in the case of improved bags, demonstrations and quantification of the benefits related with improved drying will be required to encourage adoption.

Gender

As in previous cases, both improved bagging and improved drying methods will primarily be observed by and benefit women, who traditionally manage post-harvest threshing, drying and storage, while cash outlays to purchase improved bags and dryers will be made by men. While women will more readily agree to their adoption, males who manage household finances must be convinced of their benefit with evidence of the value of the PHL reduction.

Triple- or double-bagging (which is less costly and apparently equally effective) storage technology is readily accessible and cost effective. PHL reduction initiatives should assist male and female small holders to better understand their benefits, including a quantification of the value of to PHL reduction, in order to encourage their adoption.

Improved drying technology appropriate for smallholders and adaptable to different crops represents a promising avenue of research and development in support of PHL reduction and should be incorporated into PHL reduction R&D initiatives.

3.4.3 Grains/Cereals: Teff

PHL reduction possibilities for teff were examined only for Ethiopia.

Issues/Challenges

The primary challenges facing teff farmers in Ethiopia are related with quantity losses incurred during harvesting, stocking, threshing/winnowing, and storage. If harvested too late (as is often the case), teff will shatter onto the field. Stocking losses occur from rodents and household animals eating the teff, wind, losses to the ground, and rain. Threshing losses come from the traditional use of a plastered ground surface and cattle; teff will get lost in the cracks, be contaminated with dirt, and be eaten by the cattle. Winnowing losses occur when the wind is too strong and blows the teff with the chaff. Farmers also report that losses during storage may be significant, primarily due to rodent or insect damage.

With the shift over the past ten years of teff becoming a domestic cash crop with an increase in urban teff consumption, farmers express an increased concern about quality loss: teff quality is denoted by color (the lighter the color the better), and off-farm distribution and sales increasingly require that different qualities of teff not be mixed together. Maintenance of highest quality teff depends primarily on insuring that teff is properly dried prior to storage in order to avoid quality losses from pest and moisture damage.

Key Intervention Points

Unique characteristics of teff underlie most PHL issues related with this crop. Unlike most other cereals, teff has a harvest window of less than one week between when the crop reaches physiological maturity and when grains begin to fall off the stalk and are lost. When different varieties of teff are mixed together, as is often the case, maturities will vary, making it more difficult to time the harvest.

The teff grain itself is very small and easily scattered or carried away by the wind, causing additional PHL losses during stalking, threshing and winnowing. For these reasons, PHL interventions are primarily focused on the harvesting/drying/ threshing/winnowing process.

Teff Intervention Point: Harvesting

Significant losses may be incurred due to grain shattering onto the field if not harvested during teff's short harvest window.

Solutions

1) Planting a single variety of teff to ensure that all stalks will reach maturity at the same time and permit harvesting within the short harvest window.
2) Scheduling the teff harvest so as to take place within the harvest window.
3) Harvest mechanization which is able to harvest faster and with minimal loss due to scattering, and is not dependent on the availability of hired labor.

PHL reduction programs (the Agricultural Transformation Agency (ATA), Sasakawa Global 2000, and the regional Ethiopian Institute for Agricultural Research (EIAR) centers) are focusing on mechanization. Both combine harvesters and hand-operated harvesters are being researched. Mechanization aims to reduce the issue of hiring seasonal labor and reduce the time and manual labor required for teff production.

Accessibility

1) Single seed varieties: Improved single variety teff seed is available through commercial distributers but needs to be purchased.
2) Harvest scheduling: Hired labor may not be accessible when needed and may interfere with a farmer's desire to optimally schedule the harvest.
3) Harvest mechanization: While not currently widely available, national and donor-supported programs will increase the availability of harvesters in the near future. It is expected that mechanized harvesting will be available on a custom basis to small farmers by harvester owner-operators who will charge a fee for their services.

Affordability

Since the main consideration in adopting any of the proposed solutions is whether the resulting time and financial costs are cost-effective in relation to prior losses, farmers will need to quantify the value of the PHL reduction in order to decide if the solution is cost effective (and therefore affordable). Both the purchase and use of single-variety seeds, and especially the purchase of mechanized harvesting services imply cash outlays which must be compensated with a reduction in PHL of greater value. Even improved scheduling of the harvest using conventional harvesting methods may involve incremental costs if labor is scarce during the optimal harvest window and must be bid away from other uses.

As the investment cost of mechanical harvesters will likely exceed the capacity of most small farmers – and their capacity exceeds small farmer needs – it is likely that mechanized harvesters will be purchased by farm service providers with greater access to capital or financing, who will provide mechanized harvesting service to small teff producers on a custom basis.

Adoption

Adoption of improved harvest scheduling, which may possibly entail hiring labor at a higher cost, will involve a risk-adjusted cost-benefit analysis in which SHFs will weigh the possibility of a delayed harvest and the resulting PHL against the certainty of increased labor costs to ensure an on-time harvest. Adoption decisions will depend primarily on each farmer's previous experience with delayed harvests and related losses, but may be supported with quantified estimated of the value of losses incurred due to late harvesting.

Adoption of single-variety seed in order to ensure uniform crop maturity and thereby facilitate harvesting during the short harvest window will be influenced by the natural risk-aversion to new seed varieties shown by all small farmers who are reluctant to risk their entire production on an untested new seed variety. While the practice of testing the new variety in a small portion of one's field may work in other situations, since the objective here is to plant the entire plot to a single variety so as to ensure uniform maturity, the "testing" approach will not yield the desired results. In this case, demonstration plots or the use of farmer field schools to demonstrate the benefits of a single seed variety – and the viability of specific varieties under local conditions – will be required pre-conditions to adoption.

Adoption of mechanical harvesting will again be primarily based on each farmer's own cost-benefit analysis in which the benefits, including saved labor as well as avoided losses are weighed against the cost of mechanized harvesting services. As in the case of improved scheduling, the certainty of harvesting costs will be weighed against labor costs to be incurred using traditional harvest methods and the risk of PHL due to a delayed harvest. In the absence of quantified data regarding the risk of a delayed harvest and the associated losses due to grain shattered onto the field, SHFs will have difficulty assessing the benefits of adoption and be less likely to alter traditional practice.

Gender

All three solutions are basically gender-neutral for households with both male and female adults. However, for women headed households, innovations that reduce the amount of time and labor required is critical, as they require a higher number of hired laborers and therefore spend a larger percentage of their income on labor than a male headed household. If they are unable to hire labor, they are required to wait till a male neighbor is available to help harvest, which puts them at risk of harvesting outside of peak harvest (increased quantity loss in the field) and requires them to provide a percentage of the crop to the neighbor as a form of payment.

For this reason, improved harvest scheduling may be less feasible for women-headed households due to the difficulty of hiring sufficient laborer during the peak harvest period, whereas the use of improved single-variety seed and especially mechanical harvesting offer significant benefits.

Teff Intervention Point: Threshing and Winnowing

Conventional practice following harvesting is to place the harvested stalks in a pile near the farmer's house ("stalking") while waiting to be threshed. Threshing is primarily carried out by driving cattle over the stalks to loosen the grains form the chaff. Once threshed, winnowing is done by throwing the threshed product into the air and letting the grain fall while the wind caries off the chaff. Due to the size of the teff grain and the delicacy of its attachment to the stalk – especially if harvested late – all three traditional practices present multiple opportunities for loss as the grain may be eaten by animals or insects during stalking, damaged or lost during threshing due to improper plastering of the threshing ground as well as cattle eating the teff while threshing and contamination from feces, and lost to the wind during winnowing.

Solution

Mechanized threshers offer the only significant alternative to reduce losses due to threshing and winnowing teff. Recent efforts by government and donor-funded programs have focused on adapting multi-crop threshers used internationally and adapting them to teff and to the local terrain.

Accessibility

The availability of mechanical threshers is extremely limited and in general not suited to the needs of SHFs. It is the intention of the various government and donor-funded programs working in this area to increase SHF access to mechanized threshing with the development and deployment of improved threshing technology.

Affordability

As in the case of mechanical harvesters, threshers will need to be portable and offered on a custom basis by service providers. Fees charged must be competitive with the cost of labor (and animals) involved in threshing and winnowing, as well as the value of teff lost using traditional practices. Again, until the farmers is able to accurately estimate the value of losses during threshing and winnowing, he/she will only be able to compare the cost of mechanical threshing with the cost of labor and animals involved in conventional threshing and winnowing. To the degree that these costs simply imply the use of household labor and domestic animals with little opportunity cost, SHFs may find it difficult to justify the cash outlay involved in hiring mechanical threshers with non-cash savings in terms of reduced domestic labor requirements and the use of household animals.

Adoption

As with all major technology changes, a decision to adopt mechanized threshing methods (when they become available) will entail farmer assessments of the effectiveness of mechanical threshing as well as a comparison of costs versus perceived benefits and the risk that those benefits may not be realized. As indicated above, non-cash benefits such as lower requirements of household labor may not be easily compared with cash costs.

Some teff farmers with experience with threshers believe that threshers do not properly clean the teff (fetching a lower price), and the resulting straw is unpalatable for their oxen. ATA disagrees with this last point, as threshers cut the straw and in fact increases palatably over the traditional threshing method of having livestock walk over it.

In the absence of hard evidence to the contrary, perceptions of possible benefits and non-cash savings may not be sufficient to overcome SHFs' risk aversion to radically new technologies.

Gender

Adoption of mechanical threshing technology is gender neutral as it was found that with male head of households there was a high degree of shared labor in harvest and postharvest management activities. As reported above, for women headed households, innovations that reduce the amount of time and labor requires is critical as they require a higher number of hired laborers and therefore send a larger percentage of their income on labor than a male headed household.

3.4.4 Grains/Cereals: Maize

PHL in maize was examined with respect to Kenya and Tanzania.

Issues/challenges

In Kenyan maize, SHFs are primarily concerned with quantity losses. They note a significant level of losses due to pests (larger grain borer, maize weevil, rats) and are particularly concerned with the increasing presence of LGB. Mold—especially Aspergillus spp--is also a problem and one that farmers have yet to find a satisfactory solution for in many instances. Increasingly variable rain patterns mean that cereals and beans/pulses sometimes reach maturity and must be harvested while rains continue, leading to an inability to dry sufficiently before storing.

Aflatoxin awareness varies widely, but those farmers who have heard of it are concerned but often misinformed about how to detect it (they think it can be gauged from looking for mold) and would not know what to do if they suspected its presence. There is no education or technology currently providing them with adequate solutions for aflatoxin.

Farmers in all regions of Mozambique are concerned with losses at harvest which are due to rotting as well as pest and rodent infestation in the fields. Drying, and threshing are also primary concerns for maize farmers as these three stages can account for 10 to 15 per cent in volume losses alone. This does not account for the quality losses that occur as kernels becomes damaged as farmers thresh maize by hand or by beating maize cobs that are in bags with sticks. Home storage also creates problems for the smallholder famer as losses in this stage can sometimes reach up to 50 per cent due to pests, rodents and rotting if pesticides and rodenticides are not properly administered and if maize is not properly dried before storage.

Maize growers in Morogoro near Sokoine University are able to use the University's threshing/shelling machine that rotates to the surrounding villages in accordance with harvest times. Maize farmers in Mbeya do not have this opportunity.

Maize famers would like to have machines for threshing located in field. Not only do these machines thresh and shell faster than the traditional methods of threshing – done by placing cobs in bag and then beating bag with sticks until kernels pop out or by hand using a knife to pry the kernels off the cob – but they ensure that the quality is higher. Traditional threshing methods can damage kernels and thus reduce the quality and price at marketplace. Maize farmers in Mbeya would like to have secured drying and storage facilities but both these structures are cost prohibitive for the small holder farmer. A brick drying structure – without roof – would cost roughly 1.2 million TZS to build. A proper storage facility would be 1.7 million TZS.

Key Intervention Points

Practices and impediments relating to the drying process are the primary cause of PHL in maize. Improper drying can lead to losses while the maize is still on the cob in the field. After cobs are harvested, losses during threshing, and losses during storage as the maize is exposed to fungal infections (some of which lead to aflatoxin contamination), plus insect attacks and rodents that result in both physical quantity losses and losses of quality and economic value. Even when properly dried, on-farm storage as farmers wait for improved prices expose maize to damage from insects and rodents if not properly handled. Farmers lacking proper storage facilities must endure forced sales at low harvest prices.

Conventional practice among small maize farmers is to leave the cob on the stalk after it reaches physiological maturity to dry as much as possible before being harvested and threshed. Although maize left on stalks in the field is subject to fungal, bird and insect damage and may fail to dry due to rain, cobs which are harvested while still wet are subject to even greater damage and loss from fungal infections, aflatoxin, insects and rodents, as well as continued exposure to rain. Once maize is threshed, maize kernels are sun dried to remove additional moisture before being bagged and either sold or stored on farm for household consumption or later sales. As pre- and post-harvest drying methods are dependent on the weather, increasingly unpredictable weather patterns increase the risk of inadequate drying.

Key interventions points to reduce on-farm losses include field drying/harvesting and on-farm storage. Mechanized threshing and shelling is another important innovation with significant labor saving implications, although its importance in the reduction of PHL is less than that of either improved drying and harvesting practices and technology, or improved on-farm storage methods.

Maize Intervention Point: Field Drying/Harvesting

Field drying prior to harvest is practiced primarily because post-harvest drying methods are not accessible to small producers. Larger producers with greater access to capital tend to leave their maize in the field for shorter periods and to harvest, mechanically thresh and shell the maize, and dry the kernels in mechanical dryers. Field drying has been estimated to result in from 20% to 35% loss in harvested quantity, making it the one of the largest cause of pre/post-harvest loss.

Solution

While field losses can be reduced through the use of Good Agricultural Practices, the best way to reduce losses during field drying is to harvest the ears earlier, thresh and shell them as soon as possible (preferably in mechanical threshers/shellers as traditional methods will cause greater damage to maize which is not fully dried), and dry the kernels in mechanical dryers. Other solutions include various forms on on-farm storage (discussed below) of unshelled cobs in ways which permit continued drying without exposure to pests.

Accessibility

Dryers are not currently accessible to individual SHFs due to their size and cost, and are more appropriate to the needs of either large commercial farmers or farmer-based organizations where the needs of many farmers can be met by a single dryer. As the need for dryers appropriate for individual small holders is widespread, not only in Africa but also in Latin America and Asia, it may be expected that improved solar technology or other drying methods will son result in small dryers which are appropriate and accessible to small producers.

In the meantime, the only real alternative to pre-harvest field drying combined with post-harvest sun or air drying is collectively-owned drying facilities which may be more acceptable to farmers wishing to sell their maize than those wishing to store it for home consumption.

Affordability

Cost-benefit considerations will naturally drive farmer decisions to invest in dryers if and when they become available for small holders. As in previous examples, the real cash outlay involved in the purchase of a dryer will be compared with the *perceived* benefit in terms of PHL reduction – a benefit which farmers may assume but are not easily able to quantify in order to compare with the cost involved.

Drying one's maize in a community-operated drying facility may be economically attractive to small holders, yet there are legitimate concerns about the transparency and governance of the community organization that may preclude participation in such collective activities.

Adoption

Once available, farmer decision-making regarding the purchase of an on-farm dryer will be primarily but not exclusively based on economic criteria as described above. In addition to purely financial considerations, small holders will need to be convinced that the dryers actually work and are able to bring the humidity of recently harvested wet corn down to the desired level. Demonstrations at the community level through the installation of a dryer with a lead farmer will be one way to achieve farmer confidence in the new technology.

Adoption of collective drying solutions will require significant investments in the development of farmer-based organizations where they do not yet exist, or in the strengthening of existing FBOs, including the strengthening of trust by individual farmers in the fairness and honesty of those involved in managing the collective facility.

Adoption of community-based drying will only occur with SHFs are able to both perceive the economic benefits of adoption and believe in the transparency of the FBO. As was observed in Kenya, "there is deep mistrust especially when it comes to storing maize. Maize is essentially equivalent to food in Kenya, and farmers see their own production of maize as linked to their own identity. Therefore, collective storage and marketing solutions have largely failed here."

Gender

The adoption of improved drying technologies and the avoidance of continued reliance on pre-harvest field drying may be of greater interest to male household members who are more involved with producing maize for sale, than with female members who are traditionally more involved with processing and storing maize for household consumption, as the cost of improved drying technology (on-farm or collective) can be more easily related with improve sales. Although women will benefit equally from improved drying practices, it will be more difficult to relate the benefits of reduced PHL for household consumption with the cost of improved drying technologies.

Maize Intervention Point: On-farm Storage

Smallholder farmers wishing to sell some or all of their production are frequently faced with the choice between selling their maize at low harvest prices, or storing it for sale later at higher prices but risking storage losses due to mold, fungus infections, insects or rodents which may destroy as much as 50% of the grain's value. The absence of market liquidity as well as adequate off-farm storage practices and facilities is known to cause prices to rise during the off season as much as 200% over their seasonal lows.

For farming households which destine some or all of their maize for future household consumption, the prospect of losing as much as 50% of their harvested maize to various forms of PHL imposes a serious obstacle to improving family welfare, since productive resources must be devoted to producing twice as much food as will actually be consumed.

Solutions

The development, manufacture and distribution of improved forms of on-farm storage, especially for maize, has been the primary area of focus of national and donor-funded PHL reduction programs throughout Africa, Latin America and Asia. Many forms of improved on-farm storage now exist, ranging from low cost steel and plastic silos and hermetic bags to improved versions of more traditional forms of storage such as wooden cribs. Additional research and development is needed to improve the resistance of hermetic bags to pests such as the Large Grain Borer (LGB), and to further lower the cost of fixed structures such as metal silos.

Additional solutions include collectively-operated maize storage facilities (which may be combined with collectively-operated drying facilities as described above). While such larger facilities may be technically better able to reduce PHL, organizational issues such as those described above must also be overcome in order for these solutions to be more widely accepted.

Accessibility

For farming households with sufficient funds or available financing, most of the on-farm storage solutions described above are readily accessible throughout the region, either through agricultural supply dealer networks or through government or donor-funded programs.

Affordability

The primary problem impeding increased adoption of improved on-farm storage systems is their cost as compared with the benefits they provide. Double bagging is less costly – and less effective than GrainPro hermetic bags, but most small farmers have found that the GrainPro system is not appropriate to their needs, especially for maize stored for household consumption due to the high cost of the materials. The cost of metal silos has come down, especially due to the pioneering work of RAVinvest, which is currently working in Tanzania to provide lockable metal silos for storage at the home for the smallholder farmer. Depending on size, the silo would cost between $150 and $200 and would be built in the village.

As with innovations discussed previously, the cost effectiveness of any given solution depends on a comparison between the acquisition and/or maintenance cost of the innovation and the risk adjusted expected value of the benefit to be derived. Farmer perceptions of risk are highest for untested new technologies, and are reduced as benefits are observed either in demonstration plots or in neighbors' fields. The expected value of the benefit will be generally influenced by whether the maize is for sale or home consumption, as well as a generally imprecise estimate on the value of the PHL averted. Again, decision support systems in for form of objective estimates of PHL associated with traditional and improved methods of on-form storage will be of use in supporting small farmer decision-making.

Adoption

Adoption decisions regarding improved forms of on-farm storage will be based primarily on the risk-adjusted cost-benefit analysis discussed above. (Smallholder farmers may not actually undertake a formal cost-benefit analysis, but their decision-making process will be informed by a generally very accurate informal assessment of the costs, benefits and risks involved.) Assistance in the quantification of PHL losses will help farmers to reduce the uncertainty in their analysis.

Full adoption of any improved storage method will only occur over time, as farming households adjust their thinking to the new technologies.

Gender

As in the case of improved dryers, both men, who are primarily involved with commercial sales of maize, and women, who are more involved with preparing and storing maize for home consumption, will benefit from the use of improved storage technology. Investment decisions, however, will tend to favor solutions which will improve cash sales which will offset the cost of the improved technology. In this regard, storage solutions which are primarily focused on storage for home consumption may be more difficult for small holders to justify. Decision-support systems providing quantifiable information on PHL to farmers should emphasize the cost of PHL to households where productive resources must be devoted to producing up to twice as much food as will actually be consumed.

3.4.5 Oilseeds (Groundnuts)

Since groundnuts are an important food legume in the semi-arid tropics, they face significant post-harvest issues, and are often grown by SHFs, this product represented an important example for this study. They are produced in 100 countries around the world, many of which are located in Africa because the plant prospers in areas that experience from temperatures between 27 and 33 degrees C, and with rainfall of between 260 and 1550 mm per year. That wide range notwithstanding. resource limitations necessitated that this study consider groundnuts only for Senegal and Mozambique..

Issues/Challenges

In both countries there is vibrant formal production, commerce and trade. However, most of the unshelled groundnuts are handled informally, usually by small operators. There are four main uses: home consumption, oil, confectionery, and seeds. Major differences in production practices, application of quality standards, postharvest practices, testing and relative incidence of losses between the formal and informal segments of the commodity system, and also by intended use.

The three most significant hotspots for PHL loss were identified as cultural practices, harvesting, and storage. Associated threats include quality, aflatoxin contamination, and Bruchid infestation.

Key Intervention Points

Groundnut Intervention Point: Pre-harvest

Solution

In order to achieve increased yields while also minimizing the growth of *Aspergillus flavus*, hence the generation of aflatoxin, ICRISAT has tested a variety of different cultural practices, singly and in combination, with the latter having the most control impacts by far. These include the use of soil amendments (cereal crop residues. farmyard manure, gypsum), biocontrol agents (Trichoderma culture applied to soil), seed treatments (dithane) and supplementary irrigation to avoid end-of-season drought.

Accessibility

Since none of the these measures is technologically sophisticated and they can all be taught, as long as extension agents can received the proper training, they can be accessible to most SHFs

Affordability

Farmyard manure and gypsum are relatively easy to obtain, and cheap. The biocontrol agents will need to be provided by a third party supplier initially, although over time they could be propagated locally. Dithane is an easy to obtain agrochemical. Supplementary irrigation, however, can be problematic is especially dry areas.

Adoption

It is too early to conclude much regarding levels of adoption, but it would not be hard for AGRA to partner with ICISAT to test this in a variety of contexts and countries before attempting to scale it up.

Gender

There would appear to be no particular sensitivities about this set of mitigation measures.

Groundnut Intervention Point: Harvesting

Solution

In order to maximize marketable yields while minimizing losses, harvesting should occur at optimum maturity. Damage to the pods should be avoided . Harvested materials should be left on the soil as little time as possible. Stripped pods should be dried to no more than 10% moisture (8% is better still). Sun drying before and /or after pod-stripping should be done. Diseased or infected produce should be kept separate. New, or at least clean, gunny or poly bags should be used.

Accessibility

The combination of good agricultural practices just described is very accessible to most small farmers.

Affordability

This set of practices is eminently affordable for most SHF

Adoption

High rates of adoption have been experienced by ICRISAT and others.

Gender

No evidence of significant gender differentiation or sensitivity was found thus far

Groundnut Intervention Point: Storage

Solution

In order to minimize infestation of stored crop by Bruchids, and at the same time to retard further growth of the mold *Aspergillus flavus* that often throw off aflatroxins, two types of hermetic storage are beginning to gain traction. The first is PICS triple bags (or even double bags), which is a technology that BMGF supported initially for cowpeas only but it is now spreading to other grain legumes. The second is GrainPro ultrahermetic bags and cocoons, which are offered commercially. Both would seem to have merit. PICS bags are less expensive but also somewhat less effective, especially in terms of retarding further Aspergillus growth during storage.

Accessibility

Both solutions are gaining momentum, but in somewhat different countries and with somewhat different audiences. PICS deliberately targeted SHFs, which GrainPro targets mor ecommercial farmers.

Affordability

As things evolve, the cost of both technologies is dropping, although PICS will probably always have a significant advantage in terms of upfront costs, while GrainPro solutions may have a greater ROI over time partly because of spillover effects and life cycle costing.

Adoption

Thus far, SHFs appear to favor PICS bags, at least for cowpea. It may be too early to say which technology may grab a larger percentage of the market for groundnut use.

Gender

At the household level, whether a PICS bag or GrainPro bag is used seems to be gender neutral in terms of user friendliness, although the PICS approach has the advantage of being more familiar looking to women.

At the village or community level, use of GrainPro cocoons may have the advantage of size, yet the challenge of not withdrawing product prematurely and therefore letting oxygen back into the bag, may be more difficult for women concerned with feeding their families now rather reducing lean months off in the future.

3.4.6 Oilseeds (Sesame)

PHL in sesame was studied in Ethiopia and Mozambique.

Issues/challenges

Cultivated sesame is considered to have originated from Ethiopia and to be of high quality in terms of color and oil content. With Ethiopia being the second largest sesame exporter in the world, any changes in variety, such as introduction of non-shattering varieties, will have to ensure no decrease in quality. From the smallholder farmer lens, special considerations regarding the enabling environment are needed to ensure that smallholders are not pushed out of the sesame business with the increase in mechanization and farm size. Currently, the productive sesame growing lands in the Tigray Region are approximately 70% smallholder farmer plots.

In Ethiopia, sesame farmers are aware of quantity, quality and economic losses along the value chain. However, a clear quantification of the losses varies depending on the year and on the individual practice. Factors that change between years include weather conditions (i.e. level and timing of precipitation) and market conditions (i.e. level and timing of peak price).

Sesame farmers are most concerned about quantity losses during harvesting and during *hilla* drying (a *hilla* is the stacked rows of harvested sesame bundles that are left on the field to dry). Harvesting too early will cause it to turn red when drying – a decrease in quality – and harvesting too late will cause the pods to open and shattering to occur. *Hilla* losses come in many forms from shattering, pests (particularly the sesame seed bug on wet years), rodents, wind, and rain.

Storage is also a major concern for farmers for two reasons. First, although farmers want to store for a sufficient length of time to reach peak price, they also do not want to store for so long that the sesame loses weight prior to sales, which leads to an economic loss. Second, farmers lack adequate available storage, as cooperatives and unions often either do not have available space or lack access to the capital to purchase in a timely manner. The Ethiopian Commodity Exchange (ECX) has storage, but requires farmers to sell their sesame within four months regardless of the price.

Credit is currently available prior to harvest, but access during and postharvest is necessary in order to hire laborers on a timely basis, and provide sufficient incentives to laborers to increase the level of care and harvesting steps necessary to reduce quantity PHL. The lack of access to formal credit leads to dependence on informal creditors who charge interest rates of 200-400%.

In Mozambique, Sesame farmers are particularly cognizant of losses since it is one of the most commonly grown cash crops in both of the two main agricultural regions in Mozambique (Beira and Nacala corridors.) Of greatest concern are losses associated with losing seeds in the field. When harvested too late, the sesame pods shatter and seeds are lost.

PHL mitigation activities currently practiced by farmers or promoted by government and donor-funded projects include:

In Ethiopia, simple on-farm mitigations that project implementers focus on are harvesting when senesced, stacking *hillas* in the direction of the wind, and stacking *hillas* close to the threshing area on a water permeable tarp. Agriterra and the Sesame Bureau Network (SBN) are exceptions to this, where they are focusing on identifying suitable row planting and harvesting mechanization technologies already used elsewhere that is suitable for adoption in Tigray.

Efforts are underway as well to develop non-shattering varieties that will be less vulnerable to quantity PHL.

For the most part, sesame farmers not affiliated with a donor program containing a PHL component are focusing on postharvest pest management. However, instead of taking an integrated pest management program, they focus on chemical pesticides (including DDT) either applied around the *hillas* and/or storage area, or apply directly onto the sesame.

In Mozambique, generally speaking, there is a big gap between mitigation as currently practiced and what farmers would like to do. This implies that in some cases, the gap is not created by a lack of awareness, but really a lack of access to the proper technologies. Given that these knowledgeable farmers only represent a part of the total farmer population, the rest generally do not possess the awareness to actively mitigate post-harvest loss problems. Many times, traditional techniques are viewed as the safest practice, and losses due to inefficient harvesting, storage or processing are countered by increasing volume (or at least attempting to) of harvest or yield.

There are several low technology options for farmers to reduce spillage in the field, most of which involve spreading plastic throughout the rows of the field to catch fallen seeds.

Alternatively, farmers can put plastic below drying racks to catch falling seeds, once harvested (note the latter use of plastic does not prevent the in-field spillage, which is more problematic.) Although this is an option farmers said was feasible, most are not using this technique due to the two most common barriers to adoption discussed above (cost/access constraints or lack of awareness.)

Key Intervention Points

Consistent with the issues and challenges identified by farmers and observed during field research, the two primary key intervention points are harvesting/field drying, where the objective is to avoid physical losses due to shattering either before harvesting or in *hillas*, and storage where the objective is to store sesame in order to avoid low harvest prices without loss of quality.

Intervention Point: Harvest and Field Drying (Hillas)

Due to the short harvest window and the tendency of sesame pods to shatter either in the field or in *hillas* if harvested too late or if extended rains have caused the sesame to mature early, and the difficulty of programming harvest activities to coincide with optimal harvest windows due to labor constraints, as well as unavoidable losses due to handling and transport of sesame stalks,

Solution

Solutions to the problem of shattering as a result of delayed harvest and/or rough handling during handling and transport of stalks are focused in three areas:

1) Development of non-shattering varieties which are less vulnerable to quantity PHL;
2) Improved conventional harvesting and drying practices including better-trained laborers and the use of water permeable plastic sheets between rows of stalks and underneath the hillas; and
3) Mechanized harvesting which can be better timed to void losses due to shattering of pods.

Accessibility

1) Non-shattering varieties which are appropriate to local conditions and meet quality standards are under development but are not widely available. Additional funding may be required to support the necessary research and development. Once available, these improved varieties will be distributed through normal farm supply channels and available to SHFs.
2) Improved harvesting and handling practices require only increased awareness of the benefits to be achieved through a reduction of PHL. The use of plastic sheets between rows of sesame plants requires that the sesame be planted in rows using tractors and mechanized planting, rather than using traditional broadcast methods when planted by hand. As mechanized planting may not be cost-effective to small producers, the use of plastic sheets between rows is probably limited to larger producers. The use of water permeable plastic sheeting under the *hillas* while drying requires a minimal investment and access to the plastic sheets through normal commercial networks should not pose a problem. Access to funds necessary to purchase the plastic through

formal credit for harvesting and post-harvest activities may pose a challenge as most sources of production credit do not cover harvest and post-harvest activities.

3) Mechanized harvesting is becoming more widespread among sesame producers in Ethiopia, although access may still be limited to small farmers with plots which are too small to justify the purchase of mechanized harvesting services. Smaller mechanical harvester which are either self-propelled or rely on animal traction are available from various suppliers, and depending on the size of the plot, may be appropriate to the needs of individual producers. The benefit of mechanized harvesting is the reduction in the labor required which translated to an increased ability to harvest during the short sesame harvest window since labor availability at harvest time is less of an issue. The purchase of custom harvesting services, as opposed to the use of farmer-owned small harvesters, may also pose a timing problem if excess demand for harvesting services exceeds the ability of custom providers to service all farmers within the sesame harvest window.

Affordability

1) Since the use of purchased seed is widespread among all classes of sesame producers, once improved varieties which are appropriate to local growing conditions are made available, they should pose no more affordability problems than conventional seed varieties.

2) The cost-effectiveness of using water permeable plastic sheeting under *hillas* will depend on each farmer's assessment of the benefits, in terms of reduced PHL to be achieved by using them, versus their cost. As in previous situations, although farmers are generally aware of PHL while sesame stalks are drying in *hillas*, they generally do not have a firm idea of the quantity or value of their loss, and will be unable to accurately assess the cost-benefit ratio. If the plastic is truly low-cost, the risk of error in assessing the value of the PHL to be averted will be low, making a positive cost-benefit assessment more possible.

3) The cost-effectiveness of either custom harvesting services or the purchase of a small self-propelled or animal-drawn harvester will be driven a comparison of the cost involved versus both the labor costs averted and the value of harvest losses averted by harvesting before pods begin to shatter. While the former is a fairly straight-forward calculation, the latter may be difficult to assess as although farmers are aware of losses during harvesting, they generally do not have a reliable way of calculating their cost. As in previous situations, decision-support tools in the form of information on the value of harvest-related PHL will help SHFs more accurately assess the benefits of mechanization.

Adoption

1) The adoption of improved seed varieties always presents a level of risk which small farmers find difficult to manage. While the improved variety may offer marginally improved benefits, crop failure due to insufficient adaptation of the new variety to local conditions (including disease and pests) would result in an unacceptable loss to the farmer. For this reason, the introduction of improved seed varieties always require a multi-year process of observation in test or demonstration pots, followed by at least one and possibly more years of testing in small portions of the farmer's own fields. Only after the farmer has actually developed experience with the improved variety in terms of both its agronomic and product quality as well as it reduced propensity to shatter will he/she feel comfortable in making full adoption. (As discussed above,

the cost of the improved variety should not be an issue as farmers small farmers are already accustomed to purchasing sesame seed.)

2) The adoption of improved handling practices during harvest and post-harvest handling will depend only on an awareness of the magnitude of current PHL due to rough handling, and the amount of PHL which can be averted through improved handling. There are few if any cost or cultural issues involved, although some farmers reported that monetary incentive might be necessary to get laborers to handle the stalks more gently so as to avert shattering.

3) The adoption of any form of harvest mechanization will involve a risk-adjusted cost-benefit analysis as discussed above. (Again, small farmers will not carry out a formal "risk-adjusted cost benefit analysis" such as might be expected from an MBA candidate. Surprisingly accurate informal assessments based on impressionistic data are, however, routinely carried out by small farmers as they consider the adoption of new technology.) As the risks associated with any form of new and unproven technology are perceived to be high, field demonstrations and observations of others' experiences are generally necessary in order to lower the perceived adoption risk. Even with a lowered perceived risk, the cost-effectiveness of mechanization must, of course, be positive.

Gender

A common characteristic in both Ethiopia and Mozambique is that in some sesame growing communities there is a very distinct gender separation of roles, where women focus on production of crops grown for household consumption that are physically located near the home, such as sorghum, while the men and hired-laborers will focus on sesame production. The sesame is generally grown in fields far from the home.

For this reason, the various solutions discussed here with relation to reducing PHL during the harvesting and field-drying process will be primarily of interest to and adopted by men.

Intervention Point: Storage

Since sesame is grown for commercial sale in Ethiopia and Mozambique, SHF generally must choose between selling their sesame seeds at harvest to local intermediaries, storing it on-farm, or delivering it for later sale to local or regional warehouses, including in Ethiopia, the Ethiopian Commodity Exchange (ECX). Each of these alternatives presents potential PHL issues, and none are really acceptable to SHFs. Selling at the harvest presents the obvious problem of economic PHL due to market gluts and seasonally low prices. On-farm storage without properly ventilated and protected storage facilities presents the potential for significant physical and quality losses leading to economic PHL when the sesame is finally sold. And off-farm storage pending final sale, while theoretically available in Ethiopia through the ECX and in Mozambique through farmer-owned cooperatives or associations, are not always actually available due to storage capacity constraints. An additional issue facing all sesame farmers who wish to delay their sales is the need for post-harvest financing, which is currently not widely available through banks, and may also not be available through farmer-owned associations or cooperatives in the form of advances due to a lack of capital and/or access to financial institutions.

Solution

The very lack of sufficient off-farm storage is a major contributing factor to the existence of seasonally low harvest prices. The construction of additional storage capacity would create an incentive for buyers to bid up the price at harvest in order to fill their warehouses, and for farmer-owned associations and cooperatives to take additional product off the market at the harvest, lessening the overabundance of supply which drives down prices.

Improved on-farm storage presents a somewhat less attractive solution, as each small farmer's limited needs for storage capacity (remembering that all sesame is destined ultimately for sale and not household consumption) imply storage facilities of uneconomic scale which would probably lack the various drying, humidity and pest controls which can be built into larger storage facilities. Improved on-farm storage does present a more attractive than sales at low harvest prices if the farmers lack access to larger off-farm storage facilities.

Accessibility

Access to off-farm storage is generally more available in Ethiopia than in Mozambique due to the size of the sesame industry in Ethiopia, the presence of the ECX with 55 warehouses in 17 regional locations, and the widespread presence of cooperatives and agricultural unions. Small farmers do report difficulty in accessing ECX or cooperative or union warehouses, however, due to capacity constraints at the harvest.

Farmer associations in Mozambique are less developed, although various donor-funded programs are working to mobilize and improve the capacity of FBOs. Currently Mozambican sesame farmers to not appear to have access to off-farm storage facilities where they can retain title and sell at a future date.

Improved on-farm storage facilities imply primarily the use of best practices (using correct bagging materials, avoiding bagging too close to the wall and using wooden pallets, ensuring proper ventilation and using approved forms of pest control properly. These best practices can be easily transmitted through extension agents or other means of communication (such as radio).

Affordability

Improved methods of on-farm storage do not present affordability issues, as they are essentially costless and the benefits can be easily understood by SHFs.

In order to justify off- farm storage as an alternative to harvest sales or on-farm storage, the cost-effectiveness of off-farm storage must made apparent to the SHF. While SHFs will not generally be asked to participate in providing the initial financing for the construction of new off-farm warehouses, they will be expected to pay storage fees which will include the amortization of the construction cost (unless construction is financed by government or donor organizations). The monthly or in/out storage charges charged to SHFs, as well as any additional transport and bagging costs will need to be compared to the value of the PHL averted through proper storage, or the benefit of not having to sell at low harvest prices. This is a complex calculation involving a number of separate risk factors, and the benefits of off-farm storage may not be immediately apparent to the SHF. For this reason, estimated of the amount and value of PHL in traditional forms of on-farm storage, as well as hard data on seasonal prices swings should be made available to SHFs to support their decisions to participate in off-farm storage.

Adoption

Adoption of improved forms of on-farm storage as an alternative to selling at harvest prices will require that SHFs lower their perceived risk of loss during on-farm storage. Since most SHFs have some experience with non-improved on-farm storage, it will not be difficult for them to understand and adopt improved storage techniques, as these are basically variations on traditional practices. However, whether the improvements in on-farm storage will be sufficient to make it more attractive to sales at harvest will requires a period of demonstration and testing before a farmer will be able to trust entirely in the improved storage as a preferred alternative.

In addition to the efficacy of the improved methods of on-farm storage, farmers may still be unable to avoid harvest sales if their needs for cash are great and they are unable to wait a few weeks or months before selling. Access to post-harvest financing using sesame stored in on-farm facilities is probably not an option, leaving cash-strapped farmers little alternative to harvest sales, unless they participate in a cooperative of farmers organization which is able to receive the farmer's sesame and provide an advance against future sales.

Adoption of off-farm storage (primarily available only in Ethiopia) will require that SHFs not only carry out the sort of economic analysis described above, but also that they have sufficient trust in the off-farm storage provider to act efficiently and transparently. In the case of ECX, this is generally not a problem, while in the case of cooperatives and unions, due to a lack of sufficiently trained managers this may be more of an issue. In Ethiopia, although the union and cooperative structure are well-instituted, and although they may be the appropriate level in terms of instituting mitigations that require relatively high levels of financial investment, there is a relatively low level of confidence in the cooperatives and unions from the farmer members themselves. During focus group discussions with farmer cooperative members it was a noted that cooperatives and unions are not being supported and funded by their members through development and maintenance of revolving funds to finance necessary crop purchases and provision of storage facilities.

Gender

Since sesame is grown in Ethiopia and Mozambique for sale and not for household consumption, and is frequently grown on plots located at some distance from the farmer's home, males tend to be those more involved production and sales. To the degree that farmers attempt to store their crop on-farm pending later sales at higher prices, women may become more involved as storage frequently takes place inside the house and women must receive the same training as men in improved on-farm storage practices.

3.4.7 Vegetables (Onion)

PHL in onions was examined during field research in Nigeria and Tanzania, where they are grown primarily for commercial sale.

Issues/Challenges

In Tanzania, losses in onions begin at harvesting as onions are sometimes harvested prematurely or if there is too much rain, as onions can rot while in the ground. Onions are harvested by pulling the onion leaves from the ground by hand. In the process, the leaves often break off leaving the bulb in the ground. The hoes that farmers have are not adequate for extracting these bulbs unscathed.

Storage is another problem as onions that are not dried properly can rot with losses averaging usually around 30 per cent but can be as high as 100 per cent. For onion famers in Mang'ula – a remote village in northern Tanzania – their only market is traders so the prices they receive for their onion is very low as the traders put downward pressure on prices knowing that they are the only market for Mang'ul farmers.

In Nigeria, losses also occur during harvesting because farmers harvest onions manually (About 30% of harvested onions go to waste). Losses increase especially in the rainy season because farmers harvest immature onions which are not properly cured for the market.

Losses are also recorded when market price is very poor, leaving large quantities of onions to rot away. Sizeable losses are also recorded during transportation due to the breakdown of vehicles, bad weather (heavy rainfall), and because onions are usually bagged and stacked one on top of the other causing physical damage and loss to those bags at the bottom.

Best practices using conventional technology available to small holder farmers includes improved harvest timing and avoiding harvesting immature onions while also avoiding leaving mature onions in the soil – especially during the rainy season – too long; and proper drying (curing) of onions before bagging and storage. Storage is primarily only a problem if onions have not been properly dried or cured before bagging. Bagging should be in materials allowing some degree of ventilation, and, during transport, care must be taken to ensure that bags receive ventilation and are not stacked so high as to cause damage to those at the bottom.

An important best practice observed in Mlbeya, Tanzania, it to plant onions at different times throughout the year to hedge the risk of environmental threats as well as to avoid harvesting and selling at seasonal lows prices due to market gluts.

Key Intervention Points

Reductions in onion PHL are easily available through improved planting, harvesting, drying and commercial sales practices, with little if any need for radically different technology, equipment or institutional support.

Intervention Point: Planting

Solution

Although traditional practice is to plant (and harvest) onions following traditional planting and harvest dates, depending on the locale and rainfall patterns, onions may also be planted and harvested at other times of the year, thus avoiding the low prices experienced during the traditional harvest period.

An important complement to off-season planting is contracting sales with buyers for off-season deliveries. Just as producers wish to avoid the low harvest prices, buyers are interested in securing supplies during the off season. In the absence of a contractual relationship, even if farmers are able to produce onions in the off season, market intermediaries who are accustomed to the normal production cycle may not be available to purchase the crops.

Accessibility

Local research by extensions services is required to identify other possible onion cycles in each growing region. Where agronomically feasible, the development of contractual relations with buyers will require that individual producers work together to collectively meet buyers' volume, quality and delivery needs.

Affordability

Unless expensive irrigation is required to produce onions during the off-season, there should be no additional costs related to planting onions at times other than the traditional onion cycle. The benefits of doing so are the higher prices available at times other than the traditional onion harvest.

Adoption

Adoption of planting during the off-season will depend primarily on the demonstrated feasibility of doing to. If extension-station research or the experience of lead farmers in the community demonstrates that onions can be successfully grown during the off season, SHFs may be encourage to test for growing onions outside of the normal planting/harvesting calendar in a portion of the fields. Additional adoption would depend on experience gained as well as the dynamics of the marketplace as other farms also spread out their harvest.

Unless producers have experience working together to meet buyer requirements, this may present additional difficulties, and outside assistance may be required to help individual producers understand the benefits of working together.

Gender

This solution has little if any gender implications, although men will frequently be more involved than women in cultivation of crops for commercial sale.

Intervention Point: Harvesting

Farmers in both Nigeria and Tanzania report problems in harvesting due to onions which are either immature or rotting, as well as onions which are damaged by improper field implements when the leaves break off and they need to be dug up with hoes. Farmers report losses ranging from 30% to 100% at the harvesting stage.

Solution

Given the magnitude of harvest-related losses, it is critically important that small farmers be made aware that such losses can be reduced through improved harvest timing and the use of greater care – and possibly improved field implements.

Accessibility

Improved harvest practices are easily accessible to all small holder farmers through improved extension and/or farmer field schools. As the actually harvesting will generally be carried out by hired field laborers, farmers must also be prepared to train their field laborers in proper harvesting techniques, and possibly alter compensation systems so as not to rely on quantity alone but also on the absence of immature or damaged onions.

Affordability

Improved harvesting practices should not involve increased costs.

Adoption

Some smallholder farmers see losses in crops to be part of the process of farming and that waste and spoilage along the value chain is seen as nature taking its own share from the harvest. This may be especially true in the case of onions, where a high percentage of loss at harvest appears to be assumed normal. Demonstrations of improved practices and improved results will be required before farmers will show interested in improving what they may see as normal and unavoidable.

Adoption of improved harvesting practices should not be a problem once SHFs are able to observe dramatic reductions in harvest losses and are given appropriate instruction (through extension methods such as farmer field schools).

Gender

Implementation of improved harvesting practices will involve a combination of family and hired labor. For women-headed households, improved harvest timing and improved harvest field practice may be more difficult as a higher amount of labor involved must be hired and may not be available when required.

Intervention Point: Drying (Curing)

Onions must be dried or cured for up to three weeks before they can be safely bagged and stored. If they are bagged before they are sufficiently dry, they will spoil (and the rot may spread to other onions which have been sufficiently dried).

Solution

Drying or curing onions is not difficult nor does it require specialized equipment. It just needs to be done properly before bagging. If onions are harvested during the dry season, they only need to be spread out on a dry surface until they are dry. If they are harvested during the rainy season, they will need to be moved indoors before the rain, and then moved outdoors again to continue drying. Mechanical dryers are probably neither necessary nor practical as they can do as much harm as good by overly drying the outer layers before the inner layers dry.

Accessibility

As proper drying or curing involves only a slight change in current practice and no additional technology or materials, improved practices are easily accessible and only require training by extensionists of buyers.

Affordability

For small farmers producing limited amounts of onions, adoption of improved drying practices should not involve additional cost. Larger producers may need to invest in drying sheds or racks, and will need to justify the investment cost by understanding the potential benefits.

Adoption

Improved drying practices allow small producers to store their onions rather than sell them at low harvest prices, and practices to avoid or reduce PHL during storage will be easily understood by producers. However, when sales at harvest are made in order to raise cash for urgent household expenses or to repay production loans, adoption of improved drying practices will also require solutions to the family's cash flow requirements, which may involve changes in crop financing terms or other forms of short-term financing.

Gender

Since drying activities may be carried out inside or near the house, women are more likely to become involved at this stage. Furthermore, if improved drying leads to delayed sales when cash is required for urgent household expenses, improved drying in the absence of alternate financing may create additional problems for women.

3.4.8 Vegetables (Tomato)

PHL in tomatoes was examined in Senegal, Ghana, Nigeria and Kenya.

Issues/Challenges

The extreme perishability of fresh tomatoes underlies virtually all major PHL issues affecting this crop. Mitigation strategies range from improved varieties which will not spoil as easily following harvest, to improved harvest practices, improved packing, improved transport, and contractual relationships with buyers to assure markets and avoid market gluts which sometimes result in an inability of the farmer to sell at any price and the loss of 100% of the crop.

Small farmers in all four countries visited reported a high percentage of tomatoes lost during the harvest as well as additional losses due to dehydration and accelerated ripening during transport. Harvesting is carried out at full ripe stage often leading to fast deterioration especially if there is prolonged waiting for evacuation from the farm; during long distance transportation, or other forms of handlings. Longer travel time affects the shelf life of tomatoes such that more than 50% of transported tomatoes may lost before arrival at the sales point. Bruising and crushing also contribute to heavy losses due to the storage containers that farmers use for transport.

In addition to PHL which are related with the tomato's perishability, some SHFs noted quality losses arising from the use or misuse of chemical fertilizer and pesticide application.

Key Intervention Points

Opportunities to reduce tomato PHL include:

1) Improved varieties which will keep longer following harvest
2) Improved harvest timing to avoid either unripe or overly ripe tomatoes (tomatoes which will be transported over long distances should actually be harvested before reaching full maturity, as they will continue to ripen during transport and storage)
3) Improved field and final packing materials
4) Cold storage and refrigerated transport
5) Improved on-farm drying for artisanal processing
6) Purchase-sales contracts or outgrower arrangements with fresh tomato distributors or industrial users
7) Increased processing facilities as an alternative to fresh markets
8) Forward integration of tomato producer organizations to include sorting, packing, and distribution or processing

Intervention points 1 through 5 are similar to intervention points discussed with regard to other crops considered for this study, with similar solutions, accessibility, affordability, adoption, and gender implications. Intervention points 6, 7 and 8 represent innovative opportunities for PHL reduction which have not been discussed earlier, and will be presented below. (The key intervention matrices by country and crop presented in Annex 1 present other suggested intervention points.)

Intervention Point: Purchase-sales Contracts or Outgrower Arrangements with Fresh Tomato Distributors or Industrial Users

Solution

The prospect of losing an entire crop due to the lack of a buyer is perhaps the worst risk a tomato farmer faces. The extreme perishability of the tomato increases this risk because markets must be found when the tomato is ready to be harvested – not before and not after. While price is important to buyers, of greater importance to both fresh tomato distributors and industrial processors is an assured source of supply which will reliably meet the buyer's specifications in terms of quality, volume and delivery.

Purchase and sales contracts between buyers or buyer's representatives, and organized groups of small producers have been successful in many countries. With the understanding that a purchase-sales contract must meet the needs of both parties, producers may be encouraged to organize themselves for the purpose of collectively contracting their sales and producing tomatoes which will reliably meet their buyer's specific requirements.

A separate producer- buyer relationship which was observed in the Saint-Louis zone in Senegal is the contracting of outgrowers by an industrial processing enterprise. Such arrangements do not require the degree of producer organization as do purchase-sales contracts between producer groups and buyers, and may also involve the financing of farm supplies and the provision of technical assistance to small growers to better enable them to meet the product specifications of the buyer.

Accessibility

Accessibility to either form of producer-buyer contract depends in the presence of a buyer who recognizes the advantages of contracting supplies rather than relying solely on the spot market, as well as the understand of and capacity to meet buyer specifications on the part of the producer. In the case of contracts between groups of producers and buyers, on the accessibility also depends on the capacity of small producers to organize themselves and manage a collective purchase-sale contract. Accessibility will be improved through interventions to work with producers, producer groups, and buyers to facilitate the development and implementation of such contracts.

Affordability

The primary purpose of purchase-sale contracts and outgrower schemes is to reduce risk for both parties. For this reason, such solutions to not present affordability issues to small producers.

Adoption

Adoption of purchase-sale arrangements, whether as an individual outgrower or as a member of a producer group, present significant adoption challenges to producers who lack previous experience in any sort of marketing arrangement other than the spot market at harvest. Adoption may be slow and partial, and may be threatened by the practice of side-selling (in which a producer sells previously contracted products to a third party, generally due to a more favorable price), which would destroy not only the producer-buyer relationship for the producer involved, but would threaten to destroy the prospect for future producer-buyer contracts for other SHFs. For this reason, promoters of producer-buyer contracts must aggressively discourage side-selling.

Gender

In all four countries studies, women appear to play a more prominent role than men in tomato production, harvesting, packing and sales. Women also showed a greater affinity for participation in collective activities.

Intervention Point: Increased Processing Facilities as an Alternative to Fresh Markets

Solution

Tomatoes sold for industrial uses are generally priced below those sold fresh. However, because a high percentage of tomatoes which are intended to be sold fresh are either spoiled during transportation or are abandoned when a buyer cannot be found, assured markets for industrial processing generally provide a more favorable risk-adjusted option for the farmer than fresh sales.

An increase in tomato processing capacity, especially when located near to tomato production zones, will induce additional production and market risks will be reduced, providing additional employment and income to tomato producers, the majority of which are women. An increase in tomato processing facilities will also in itself be a source of additional employment which again tends to favor women.

Accessibility

Access to increased processing facilities will depend on factors generally outside the control of individual small producers, and will include government investment policy, foreign investment policy, and investment incentives or facilitation which may be provided through donor-funded programs.

Affordability

Both the decision to invest in new or expanded processing facilities and the decision by small producers to produce and sell tomatoes to industrial processors will be made based on economic criteria. Investors in processing facilities must be assured an adequate return on their investment commensurate with the risks involved, while producers will decide between selling to industrial processors and selling to distributors of fresh tomatoes based on the prices paid and the various risks involved. Judging from comments received from producers in all four countries, given current relative prices for fresh and industrial tomatoes, most producers would favor increased opportunities to sell to industrial users.

Adoption

Given the increased risks involved with the distribution and sale of fresh tomatoes, and based again on comments received from tomato producers in all four countries, when increased processing capacity is available most producers will welcome the alternative to sell some or all of their harvest to processors at current relative prices. Naturally, the price relationship between industrial and fresh tomatoes may change with the presence of additional processing capacity.

Gender

As women are generally more involved in tomato production than men, an increase in both the demand for tomatoes due to the presence of additional processing capacity, as well as an increase in processing capacity itself will create additional employment opportunities for women, either as suppliers to or employees of industrial tomato processors.

Intervention Point: Forward Integration of Tomato Producer Organizations to Include Sorting, Packing, and Distribution or Processing.

Solution

Forward integration into processing and/or distribution is really a variation on the previous two interventions, and one which has been proven successful in countless instances throughout the world. Producer-owned cooperatives and similar organizations have proven themselves to be among the best organizational formats to protect producers' interests by collectively carrying out the various sorting, packing, processing and marketing activities and ensuring that the benefits of these activities accrue to the producers rather than value chain intermediaries or other participants.

Accessibility

While producer-owned processing and marketing organizations such as cooperatives may offer the highest level of benefits to individual producers, they are also the most difficult to manage, primarily due to the lack of small holders' education and experience in business management. Concepts such as cooperative retains, the need for working capital, and the recovery of costs associated with processing and marketing may pose difficulty to relatively unsophisticated small producers who are ultimately responsible for the organization's management.

Affordability

While a well-managed cooperative will provide financial benefits for its members beginning in year one, some initial investment will be required and should not be entirely born by governments or donor-funded programs. Where initial investments by new members is beyond the reach of SHFs, long-term financing or additional discounts from future earnings may be considered.

Adoption

Membership in a producer-owned organization such as a cooperative may be a major change for a small producer without previous experience in similar organizations. Trust in the organization's leadership and management structure, as well as in its institutional supporters will be important in order to reduce the perceived risk of relying on the organization to receive, process, and market the producer's crop – and to pay him/her a better price that what is available in the market. Promoters of such producer organizations will benefit from applying standard adoption theory in the case by the identification and early incorporation of local opinion leaders and other early adopters, while demonstrating benefits and transparency in order to subsequently attract the late adopters.

Gender

Both men and women need to be involved at an early stage in the development and implementation of producer organizations to receive, process, and collectively market tomatoes: Women, because they are the ones who are generally most heavily involved tomato production and sales, and are also generally more favorable disposed to collective arrangements and to innovative behavior; and men, because they frequently either control or share control over family financial resources.

For highly perishable commodities such as tomatoes, producer organizations such as cooperatives which are able to add value to their members' agricultural production and assure market access are among the most effective strategies to integrate value chains and reduce PHL. They are also the most difficult to implement in societies with reduce literacy and numeracy capacity. Interventions to develop producers' capacity to form and manage such

organizations may offer the greatest long-term benefits to both reduce PHL and increase small farmer incomes, especially for women.

4. Sources

This review provides an annotated bibliography of key reports from main postharvest loss (PHL) investigators and implementers, as well as a basic bibliography of other relevant sources. It also includes references and descriptions of already existing postharvest loss literature and data repositories.

(Note: Since there is a significant amount of postharvest loss literature available, this review focused mainly on PHL literature relevant to: smallholders; innovations in mitigation; adoption; targeted commodities; and targeted countries.)

4.1 Information/Data Repositories

The ADM Institute for the Prevention of Postharvest Loss at the University of Illinois at Urbana-Champaign provides a strong resource list for literature focusing on postharvest loss technologies, market-based approaches, investigation methods, and loss estimates and measures. (http://postharvestinstitute.illinois.edu/literature.html).

Key Words: SSA, W. Africa, E. Africa, Southern Africa, Ethiopia, grains, wheat, rice, fruits, vegetables, roots, food security, storage, technologies

The African Postharvest Losses Information System (APHLIS) is an interface for a calculator of national-level postharvest loss estimates by crop, country and province in East and Southern Africa through tables and interactive maps (http://www.aphlis.net/).

Key Words: Senegal, Ghana, Nigeria, Ethiopia, Kenya, Tanzania, Mozambique, maize, teff

The Global Donor Platform for Rural Development has postharvest losses as one of its main topic areas and provides a repository of key publications and a research library on postharvest loss (http://www.donorplatform.org/postharvest-losses-and-food-waste/on-common-ground).

Key Words: postharvest loss, food loss and waste, technologies, processing, storage, farm-level, regional-level, national-level, economics, gender, socioeconomics, grain, rodent, termite, mycotoxins,

HGCA. *Grain Storage Guide for Cereals and Oilseeds*. 3rd ed. Warwickshire: Agriculture & Horticulture Development Board (AHDB): 2011. http://www.hgca.com/media/178349/g52_grain_storage_guide_3rd_edition.pdf

Key Words: Hazard Analysis and Critical Control Point (HACCP) system, food safety

Note: Also available (http://www.hgca.com/grainstorage) are manuals on grain store management, effective grain sampling, storage pest control, and grain drying and cooling.

The Post-Harvest Innovation Learning Alliance coordinates organizations and individuals working with postharvest loss innovations. It originated from the project, *Post-harvest innovation: enhancing performance at the interface of supply and utilization* (http://projects.nri.org/phila/).

Key Words: Tanzania, Zimbabwe, innovation systems, case studies, program reports

4.2 Annotated Bibliography

Harris, KL, & Lindblad, CJ. American Association of Cereal Chemists. *Postharvest Grain Loss Assessment Methods - A Manual of Methods for the Evaluation of Postharvest Losses*. Washington, DC: Office of Nutrition, USAID, 1976. http://pdf.usaid.gov/pdf_docs/PNAAG842.pdf

This manual is still considered by postharvest experts to be the definitive manual on measuring and evaluating postharvest grain losses in the field. It provides sampling and measurement techniques that are sensitive to the local context and culture. This can be used to develop baselines and monitor effectiveness of technology-based innovations. However, it was developed prior to the introduction of the Larger Grain Borer in Africa and it does not cover other crop types outside of grains.

Food and Agriculture Organization (FAO), World Bank. (2010). *FAO/World Bank workshop on reducing post-harvest losses in grain supply chains in Africa: Lessons learned and practical guidelines*. Retrieved from http://www.fao.org/fileadmin/user_upload/ags/publications/FAO_WB_ph_web.pdf

This workshop brought together experts in PHL (including the private sector) to discuss the significance of the issue, past experiences, and appropriate solutions for Sub-Saharan Africa (SSA). As cereal grains constitute the basis for food security for the majority of the population in SSA and are a vital component in the livelihoods of smallholder farmers, the experts convened and technologies discussed focused on cereals. Consensus arose on the need to: build political support and increase funding; reinvigorate a community of practice; involve private agribusiness firms and solution providers, and to treat cassava as a crop of interest due to its high consumption rate in SSA.

Gustavsson, J, Cederberg, C, Sonesson, U, van Otterdijk, R, & Meybeck, A. (2011). *Global Food Losses and Food Waste: Extent Causes and Prevention*. Rome: FAO. Retrieved from http://www.fao.org/docrep/014/mb060e/mb060e.pdf

The study uses a value chain approach to identify the location and magnitude of losses occurring along it, and offers possible prevention options. The term “food loss and waste” is suggested to allow a distinction not evident in the term “postharvest loss” between involuntary loss in quantity and quality at the supply-side and waste that involves a voluntary decision. Loss is characterized as an issue more relevant to developing countries, while waste is more important in developed countries. The study used the FAO 2009 Statistical Yearbook production volumes, an extensive literature search, and 2007 Food Balance Sheets. It was challenged by major data gaps for both the percentages and causes of losses and waste.

International Development Research Centre, ICIPE (African Insect Science for Food and Health). (2013, February). *Postharvest Losses in Africa: Analytical Review and Synthesis - Gaps and outlook for future postharvest research and innovation in sub-Saharan Africa*. Retrieved from Dr. Hippolyte Affognon, ICIPE.

The study assessed the areas and magnitude of PHL in Tanzania, Mozambique, Kenya, Ghana, Benin, and Malawi. Value chains included cereals, horticulture, roots/tubers, pulses, oilseed, fish, and meat and dairy. The definitions and conclusions reached were the same as the World Bank and FAO in regards to PHL in SSA and the adoption of a value chain approach, but the study highlighted critical gaps in cost-benefit analyses of innovations within local contexts and in adoption studies. Country-level action plans by value chain were developed focusing on future PHL research and innovations.

World Bank, FAO, Natural Resources Institute (NRI). (2011, April). *Missing Food: The Case of Postharvest Grain Losses in Sub-Saharan Africa* (Report No. 60371-AFR). Retrieved from http://siteresources.worldbank.org/INTARD/Resources/MissingFoods10_web.pdf

After increased global food prices from 2006-2008 brought renewed interest to the areas of food security and agriculture, this report was published to highlight an often neglected aspect that exacerbates food security and smallholder farmer livelihood: PHL. The report is based on a desktop study that NRI conducted. A supply chain view is recommended to give a systemic approach to solve low adoption rates of PHL mitigation in SSA. It expands the definition of PHL beyond quantity losses to include quality and economic losses. It is a review of technologies and practices, responses, and lessons learned and recommendations. It focuses on cereals and roots/tubers within SSA.

4.3 Basic Bibliography

Agribusiness in Sustainable Natural African Plant Products. (2013). *Sahelian Onion Productivity and Market Expansion Program – SOPMEP*. Retrieved April 30, 2014 from http://www.asnapp.org.za/index.php/programs/ghana-liberia/sahelian-onion-productivity-and-market-expansion-program-sopmep

Key Words: Ghana, onion, storage

Bokusheva, R., Finger, R., Fischler, M., Berlin, R., Marín, Y., Pérez, F., Paiz, F. (2012). *Factors Determining the Adoption and Impact of a Postharvest Storage Technology*. Retrieved from http://ageconsearch.umn.edu/bitstream/125138/2/Postcosecha_IAAE_2012.pdf

Key Words: Grains, metal silo, enabling environment, household socio-economics

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. (2013). *The Ecological Footprint of Cassava and Maize Post-Harvest-Losses in Nigeria: A Life Cycle Assessment*. Retrieved from http://www.donorplatform.org/postharvest-losses-and-food-waste/research-library#determination-assessments-analysis

Key Words: Nigeria, cassava, maize, processing, environmental impacts, biodiversity,

FAO. (2014). *Appropriate food packaging solutions for developing countries*. Retrieved from http://www.fao.org/docrep/015/mb061e/mb061e00.pdf

Key Words: Trade, policy, technology, product development, supply-side, demand-side, packaging

FAO. (2010). *Training Manual: Good Agricultural Practices (GAP) on horticultural production for extension staff in Tanzania*. Retrieved from http://www.fao.org/docrep/013/i1645e/i1645e00.pdf

Key Words: Tanzania, agribusiness development, contract farming, extension, farmer groups, food safety, market access, traceability

FAO. (1999). *The Use of Spices and Medicinals as Bioactive Protectants for Grains*. Retrieved from http://www.fao.org/docrep/x2230e/x2230e00.htm

Key Words: Grains, on-farm storage, pest management

FAO. (1998, January). *Storage and Processing of Roots and Tubers in the Tropics*. Retrieved from http://www.fao.org/docrep/X5415E/X5415E00.htm

Key Words: Cassava, cost-benefit analysis, gari, handling, processing, nutrition, storage

FAO. *Grain storage techniques: Evolution and trends in developing countries*. FAO Agricultural Services Bulletin No. 109. Ed. D.L. Proctor. Rome: 1994. http://www.fao.org/docrep/t1838e/T1838E00.htm#Contents

Key Words: Economics, mycotoxins, grain standards, harvesting, threshing, cleaning, drying, storage, warehousing, insect, rodent

Fox, T, & Fimeche, C. Institution of Mechanical Engineers. (2013). *Global Food: Waste Not, Want Not*. Retrieved from https://archive.org/details/553639-global-food-waste-not-want-not

Key Words: food losses and waste, estimates, processing, storage, transportation, marketplace

Grolleaud, M. (2002). *Post-harvest losses: Discovering the full story*. Rome: FAO.

Key Words: Postharvest losses, control, technology, socioeconomic environment, surveys

Hodges, RJ, Buzby, JC, & Bennett, B. (2010). Postharvest losses and waste in developed and less developed countries: opportunities to improve resource use. Journal of Agricultural Science, 149 (51), 37-45. Retrieved from http://ucanr.edu/datastoreFiles/234-2203.pdf

Key Words: Sub-Saharan Africa, US, UK, cereals, collective marketing, technologies

International Commission of Agricultural Engineering (Ed.) (1999). *CIGR Handbook of Agricultural Engineering Volume IV*. Retrieved from http://www.cigr.org/documents/CIGRHandbookVol4.pdf

Key Words: agroprocessing, cassava, cold storage, drying, grains, onion, pre-harvest influences, quality standards and testing, smallholder, storage

International Institute of Tropical Agriculture, & Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbHThe. (1997). *From Biological Control to a Systems Approach in the Post Harvest Sector – Stored product protection of on-farm maize in Sub-Saharan Africa*. Retrieved from http://www.fastonline.org/CD3WD_40/INPHO/VLIBRARY/MOVE_REP/X0294E/EN/X0294E00.HTM

Key Words: systems approach, Larger Grain Borer, maize, storage, Prostephanus Truncatus

Kader, AA. (2013). *Postharvest Technology of Horticultural Crops – An Overview from Farm to Fork*. Ethiopian Journal of Applied Sciences and Technology. (Special Issue No.1): 1-8. Retrieved from http://ucce.ucdavis.edu/files/datastore/234-2531.pdf

Key Words: fresh produce, fruits, postharvest losses, quality, safety, vegetables

Kansas State University. (2013, December 11). *University establishes multimillion-dollar global food security program on reducing postharvest loss*. Retrieved from https://www.k-state.edu/media/newsreleases/dec13/ftfpostharvest121113.html

Key Words: Feed the Future, Innovation Lab, postharvest loss

Kitinoja, L., & Thompson, J.F. (2010, June). *Pre-cooling systems for small-scale producers*. Stewart Postharvest Review, 2 (2). doi: 10.2212/spr.2010.2.2

Key Words: Cost/benefit comparison, horticulture, pre-cooling systems, portable, postharvest, mobile, small-scale

Navarro, H., Navarro, S., Finkelman, S. (2011, July). ***Hermetic and Modified Atmosphere Storage of Shelled Peanuts to Prevent Free Fatty Acid and Aflatoxin Formation*****. Retrieved from http://www.researchgate.net/publication/236157231_Hermetic_and_modified_atmosphere_storage_of_shelled_peanuts_to_prevent_free_fatty_acid_and_aflatoxin_formation**

Key Words: Aflatoxins, Colony Forming Units (CFU), Free Fatty Acid (FFA), hermetic, moisture content, peanut, polyethylene bag, SGBIIZ bag, storage

Nyambo, BT. (1993). ***Post-harvest maize and sorghum grain losses in traditional and improved stores in South Nyanza district, Kenya. International Journal of Pest Management*****, 39(2), 181-187.**

Key Words: Kenya, maize, sorghum, traditional storage, improved storage, gravimetric method

UNDP African Facility for Inclusive Markets. (2012). ***The Roles and Opportunities for the Private Sector in Africa's Agro-Food Industry*****. Retrieved from http://www.undp.org/content/dam/undp/library/corporate/Partnerships/Private%20Sector/Market%20Study.pdf**

Key Words: private sector incentives, investment, smallholder engagement, inclusive market development models

USAID, Dry Grain Pulses Collaborative Research Support Program (CRSP). (2013). ***Five-Year Program Technical Report 2007-2012*****. Retrieved from http://legumelab.msu.edu/uploads/files/PulseCRSP2007-2012Report.pdf**

Key Words: Kenya, Mozambique, Nigeria, bean, cowpea, lablab, maize, pre-harvest influences, pulses, storage, solarization, triple bagging

USAID, Dry Grain Pulses Collaborative Research Support Program (CRSP). (2012, July). ***Impact Assessment Research Brief*****. Retrieved from http://crsps.net/wp-content/downloads/Dry%20Grain%20Pulses/Inventoried%208.22/4-2012-2-134.pdf**

Key Words: Nigeria, Senegal, ash storage, cowpea, Internal Rate of Return, metal drums, Net Present Value, storage, solarization, triple bagging

USAID, Horticulture Collaborative Research Support Program (HortCRSP). (2013, March). Sections Three, Four, and Five. ***In Annual Report 2010-2011*** **(pp. 31-35, 47-58, 75-80, 87-94,109-112, & 133-134). Retrieved from http://hortcrsp.ucdavis.edu/main/media%20page/2010Annual_Report_smaller.pdf**

Key Words: Ghana, Kenya, Nigeria, Tanzania, biocontrols, cold storage, cold transport, market access, solar drying, tomato, vegetable

USAID, HortCRSP. (2011, March). ***Feasibility analysis of the CoolBot*****. Retrieved from http://hortcrsp.ucdavis.edu/main/Deliverables/Reid_report_feasibility_analysis_of_coolbot.pdf**

Key Words: Cassava, CoolBot, cold storage, cost-benefit analysis, onion, tomato

World Resources Institute (WRI). (April, 2014). ***Overview: Food Loss and Waste Protocol*****. Retrieved from http://www.wri.org/sites/default/files/uploads/Food_loss_and_waste_protocol_Summary_Overview_April_2014.pdf**

Key Words: Measurement protocol, multi-stakeholder, tiered methods