

ECONOMIC AND SECTOR WORK

MISSING FOOD:
The Case of Postharvest Grain
Losses in Sub-Saharan Africa



APRIL 2011



THE WORLD BANK

REPORT NUMBER 60371-AFR

MISSING FOOD:

The Case of Postharvest Grain Losses in Sub-Saharan Africa

Report No. 60371-AFR



THE WORLD BANK
Washington, D.C.



Natural
Resources
Institute



© 2011 The International Bank for Reconstruction and Development / The World Bank
1818 H Street, NW
Washington, DC 20433
Telephone 202-473-1000
Internet www.worldbank.org/rural
E-mail ard@worldbank.org
All rights reserved:

This volume is a product of the staff of the International Bank for Reconstruction and Development / The World Bank; the Natural Resources Institute, United Kingdom; and the Food and Agriculture Organization of the United Nations (FAO). The findings, interpretations, and conclusions expressed in this paper do not necessarily reflect the views of the executive directors of The World Bank or the governments they represent.

The World Bank does not guarantee the accuracy of the data included in this work. The boundaries, colors, denominations, and other information shown on any map in this work do not imply any judgment on the part of The World Bank concerning the legal status of any territory or the endorsement or acceptance of such boundaries.

Rights and Permission

The material in this publication is copyrighted. Copying or transmitting any of this work without permission may be a violation of applicable law. The International Bank for Reconstruction and Development / The World Bank encourages dissemination of its work and will normally grant permission to reproduce portions of the work promptly.

For permission to photocopy or reprint any part of this work, please send a request with complete information to the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, USA, telephone 978-750-8400, fax 978-750-4470, www.copyright.com.

All other queries on rights and licenses, including subsidiary rights, should be addressed to the Office of the Publisher, The World Bank, 1818 H Street NW, Washington, DC 20433, USA, fax 202-522-2422, e-mail pubrights@worldbank.org.

Cover Photo: Rick Hodges, NRI

CONTENTS

Acknowledgments	vii
Acronyms and Abbreviations	ix
Executive Summary	xi
1. Introduction	1
2. Nature and Magnitude of PHL for Grains in Sub-Saharan Africa	5
3. Technologies and Practices to Reduce PHL: A Review	21
4. Responses to PHL Reduction	37
5. Lessons Learned and the Way Forward	43
6. References	49
Annex 1. Questionnaire Survey Respondents and Areas of Experience	57
Annex 2. Postharvest Project Profiles	59
Annex 3. Benefits, Costs, and Degree of Adoption of Technologies	81
Annex 4. Overview of PHL-Reduction Practices by Different Organizations	85
Annex 5. Community Grains Banks: History and Lessons	87
Annex 6. Viewing Postharvest Innovation Systems	93
Annex 7. Practical Experiences of Using Risk Management Instruments	95

LIST OF BOXES, FIGURES, AND TABLES

BOXES

Box 1.1. Coordinating bodies for grains postharvest development	2
Box 1.2. The key role of economic incentives in PHL reduction	2
Box 2.1. Maize value related to damage	9
Box 2.2. Findings of PHL assessment surveys	10
Box 2.3. Increasing use of bag storage in Tanzania	11
Box 2.4. Responding to bumper harvests	12
Box 2.5. Examples of large-scale storage facilities in African countries	13
Box 2.6. Role of metrology	14
Box 2.7. The impact of market liberalization on commercial grain storage and marketing	15
Box 3.1. Mud silo promotion in Northern Ghana (Annex 2, Project 13)	26
Box 3.2. Farmers' benefits from using the silo— Central America	27
Box 3.3. The lessons learned in metal silo promotion in Central America by the Swiss agency for development and cooperation (SDC) PostCosecha project	28
Box 3.4. Good storage hygiene is the single most important element in maintaining grain quality and reducing PHL during storage.	32
Box 3.5. Warehouse receipts systems	34
Box 4.1. Learning alliances for PHL reduction	42

FIGURES

Figure 2.1. Structure of Total Grain Production of 112 Million Tons in SSA	6
Figure 2.2. Countries in SSA where Irrigated Lowland NERICA Varieties Have Been Released or Are Being Tested.	6
Figure 2.3. Grain Production in SSA, 1961–2008, Million Tons	7
Figure 2.4. Illustration of a Generic Value Chain for Maize	8
Figure 2.5. Maize Drying in the Yard	9
Figure 2.6. Maize Drying in a Crib.	10
Figure 2.7. Winnowing.	10
Figure 2.8. Indoor <i>Kihenge</i> (woven granary) and Sacks.	11
Figure 2.9. Taking the Harvest Home by Oxcart	12
Figure 2.10. Travel Time to Market for Farmers in Ethiopia, Kenya, Tanzania, and Uganda	13
Figure 2.11. Estimated Percentage of Cumulative Postharvest Weight Loss from Production of Various Grains in East and Southern Africa for 2007.	18
Figure 3.1. Examples of Strategies to Reduce PHL and Promote Overall Postharvest System Improvements	22

Figure 3.2. IRRI-Type Two-Wheeled Tractor Provides Transport, Can Be Used for Tillage, Harvesting, Shelling, or Threshing	23
Figure 3.3. Sealed Stores—Mud Silo (a) and Metal Silo (b).	25
Figure 3.4. IRRI Super Bag (the gas- and moisture-proof liner).	29
Figure 3.5. Plastic Granary (left) and the Traditional Mopane Wood Model (right)	29
Figure 3.6. Hermetic Grain-Storage Envelope Sealed Shut with a Gastight Zip in Rwanda	31
Figure 4.1. Recommendations for Future Interventions to Improve the Quality and Quantity of Grain Supply in SSA (expressed in percent of suggested projects)	40
Figure 5.1. Trade and Welfare Reduction Indexes, All Covered Products, 19 African Countries and Regional Average, 2000–04	46
Figure A6.1. A Postharvest Agricultural Innovation System	93
Figure A6.2. A Postharvest Agricultural Innovation System from the Farmer’s Perspective	93

TABLES

Table S.1. Framework for Distinguishing the Objectives and Target Groups for Future of PHL-Reduction Interventions	xvii
Table 2.1. Indicators of Grain Production and Imports in Africa	7
Table 2.2. Mean Household Income Shares Spent on Food in SSA	8
Table 2.3. Causes of PHL (in percent to total losses)	9
Table 2.4. Possible Impacts on Smallholders of PHL under Liberalized Markets	15
Table 2.5. Generalized Loss Profiles for Major Grains in Eastern and Southern Africa	17
Table 2.6. Mean Estimates of PHL for Grains in Ghana, % of Total Production	19
Table 2.7. Estimated Value of Weight Losses for Eastern and Southern Africa Based on Annual Production and Estimated % PHL, 2005–07 Average.	19
Table 3.1. Spillover Effects from the ASSI Thresher Cleaner	24
Table 3.2. Hermetic Sacks and Hermetic Large-Scale Envelopes Used in Africa	29
Table 4.1. Chronology of Postharvest-Related Interventions and Approaches in Grain Chains	38
Table 5.1. Expected Impact of PHL Interventions on Self-Sufficiency and Incomes.	45

ACKNOWLEDGMENTS

This report was prepared by Sergiy Zorya, Agricultural and Rural Development (ARD) Department World Bank; Nancy Morgan, the Food and Agriculture Organization (FAO) liaison to the World Bank; and Luz Diaz Rios, ARD Department, World Bank, based on the background papers prepared by Rick Hodges and Ben Bennett from the Natural Resources Institute in the United Kingdom.

This report was developed in collaboration with the UN FAO. Stephanie Gallat, Divine Njie, and Edward Seidler provided valuable professional support. The FAO organized and provided financial support for the technical workshop in Rome. The overall task was led by John Lamb, Agricultural and Rural Development Department, the World Bank.

Heartfelt thanks to the postharvest specialists who willingly contributed to this review. Many considered the job important enough to donate many hours to it; they gave freely of their time, which is a scarce resource. It has been a pleasure to add their views and comments into the review. Their names are listed in Annex 1. The report has also benefited from the presentations and discussions at the technical workshop in Rome on March 18–19, 2010. Special thanks are due to the authors who made the presentations there: Ulrich Boysen (African Development Bank), Ken Davies and Bertrand Salvignol (World Food Program), Jonathan Coulter, Felix Rembold (Joint Research Center of the European Commission), Chakib Jenane (UNIDO), Julia Seevinck and Divine Njie (FAO), and the private sector representatives Tom Gambah (Premium Foods Ltd, Ghana), Paulo Chiziwa (Grain Traders and Producers Association, Malawi), Philippe Villers (Grainpro Inc.), Harriet Nabirye (Eastern Africa Grain Council), and Anthony Mwanaumo (Zambia Food Reserve Agency).

Stephen Mink from the World Bank and Steven Schonberger from the International Fund for Agricultural Development suggested many improvements to the report through peer review comments. Mark Cackler (Sector Manager, ARD) and Karen McConnell Brooks (Sector Manager, AFTAR) provided wise guidance and encouragement throughout the project.

ACRONYMS AND ABBREVIATIONS

AfDB	African Development Bank
APHLIS	African Postharvest Losses Information System
CFC	Common Fund for Commodities
CFS	Committee on World Food Security
CGA	Grain Growers Association of Kenya
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Centre
CRS	Catholic Relief Services
DE	Diatomaceous Earth
DFID	Department for International Development, United Kingdom
EAGC	Eastern Africa Grains Council
EU	European Union
FAO	Food and Agriculture Organization
FAOSTAT	FAO Statistical Database
FONADES	Fondation Nationale pour le Développement et la Solidarité
GAP	good agricultural practices
GASGA	Group for Assistance on Systems Relating to Grain after Harvest
GMP	good manufacturing practices
GTZ	German Technical Assistance
HIV/AIDS	Human Immunodeficiency Virus/Acquired Immune Disease Syndrome
HYV	High Yielding Varieties
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
INPhO	Information Network on Postharvest Operations
IRRI	International Rice Research Institute
ISCOS	Institut Syndical pour la Cooperation au Development
KMDP	Kenya Maize Development Program
LA	Learning Alliance
LGB	Larger Grain Borer (<i>Prostephanus truncatus</i>)
MFI	Microfinancing Institution
NCPB	National Grains and Produce Board
NERICA	New Rice for Africa
NGO	Nongovernmental Organization
NRI	Natural Resources Institute
P4P	Purchase for Progress
PFL	Prevention of Food Losses
PhAction	Postharvest Action (Global Postharvest Forum, formerly GASGA)

PHILA	Postharvest Innovation Learning Alliance
PHL	Postharvest Losses
SDC	Swiss Agency for Development and Cooperation
SSA	Sub-Saharan Africa
UN	United Nations
WARDA	Africa Rice Centre
WFP	World Food Programme
WRS	Warehouse Receipt System
ZAMACE	Zambian Agricultural Commodity Exchange

EXECUTIVE SUMMARY

BACKGROUND

Low-income, food-deficit countries have become especially concerned about the global and national food situation over the past three years. While the proximate cause of this heightened concern was the surge in food prices that began in 2006 and peaked in mid-2008, concerns remain for other reasons, among them the higher market-clearing price levels that now seem to prevail, continuing price volatility, and the risk of intermittent food shortages occurring repeatedly far into the future. For lower-income Sub-Saharan Africa (SSA) countries, ongoing contributing factors include persistently low productivity, difficulty adapting to climate change, financial difficulties (inability to handle the burden of high food or fuel prices or a credit squeeze), and increased dependence on food aid. Yet there is an additional, often-forgotten factor that exacerbates food insecurity: postharvest losses (PHL). They can and do occur all along the chain from farm to fork, which reduces real income for all consumers. This especially affects the poor, as such a high percentage of their disposable income is devoted to staple foods.

Interest in the reduction of PHL is not new. After the mid-1970s food crisis, considerable development investment went into PHL reduction for staple crops. In fact, in 1975, the United Nations brought postharvest storage losses into international focus when it declared that “further reduction of postharvest food losses in developing countries should be undertaken as a matter of priority” (FAO 1981). Unfortunately, once real commodity prices resumed their historical downward trend, the policy shifted to emphasize food security through economic liberalization and trade. The world seems to have forgotten the importance of postharvest food losses in the African grain sector, and those networks or programs that sought to reduce them, such as FAO’s Prevention of Food Losses Program and the Global Postharvest Forum (PhAction), have fallen into abeyance. The low adoption of the PHL technologies promoted in various SSA countries has also led to the declining investments in this area.

With renewed emphasis on agriculture, and in the aftermath of the recent food and financial crises, the profile of PHL has been significantly raised. Interventions in PHL reduction are seen as an important element of the efforts of many agencies to reduce food insecurity in SSA. PHL is increasingly recognized as part of an integrated approach to realizing agriculture’s full potential to meet the world’s increasing food and energy needs. Therefore, reducing PHL—along with making more effective uses of today’s crops, improving productivity on existing farmland, and sustainably bringing additional acreage into production—is critical to facing the challenge of feeding an increased world population. Postharvest losses feature prominently in recent global initiatives such as the Comprehensive Framework for Action issued in 2009 by the UN High-Level Task Force for Food Security and Nutrition after the global food crisis, the Global Agricultural and Food Security Program endorsed by the World Bank in January 2010, and the recently reformed Committee on World Food Security (CFS).

It is clearly recognized that the context of agricultural production and marketing in SSA has evolved since the 1970s and 1980s, as have the challenges associated with PHL reduction. Changes have included (i) increasing competition from international markets in the wake of market liberalization; (ii) the state’s withdrawal from grain marketing activities that provided the commercial sector with variable technical support in grain handling and storage; (iii) development of more sophisticated grain value chains coordinated by an emerging private sector; (iv) increased regional integration, which has resulted in the easier movement of grain but with limited monitoring of quality; (v) impacts of HIV/AIDS and urbanization on labor availability; (vi) spread of the larger grain borer, a devastating storage pest; (vii) introduction of varieties with high yield that require inputs and are more susceptible to pest attack; (viii) increasing land fragmentation, with a corresponding decrease of farm

size, accompanied by declining soil fertility; (ix) erratic weather patterns that have led to recurrent failures in harvests and consequent food shortages; and (x) the erosion of postharvest expertise to serve the needs of developing country producers and supply chains.

Limited success in reducing PHL and a shrinking technical capacity to respond to the challenges of PHL reduction highlight the need to build up a knowledge base of lessons to raise the profile of PHL and to provide best practices and practical recommendations for scaling up. Consequently, the World Bank undertook this policy-oriented research of the current state of knowledge and technology related to PHL reduction. It did so in collaboration with FAO, with the expertise of the U.K. Natural Resources Institute, and with contributions of key PHL stakeholders and institutions, capturing lessons from past interventions that could provide insights for the implementation of effective PHL strategies. This analysis looks at the evolution of public and private sector responses over the last two decades to reduce losses along the various stages of the supply chains and supports and to build on the African Development Bank's current Post Harvest Loss Initiative for SSA. It also highlights critical factors that determine technology uptake and sustainable use, with a focus on gender dimensions of technology adoption for reducing PHL. The main findings of this research are discussed in the following pages.

PHL OF GRAINS IN SSA REMAIN SIGNIFICANT

While the profile of PHL has been raised for a number of commodities in SSA, this report focuses on grains, which still constitute the basis for food security for the majority of the population in the region and are a vital component in the livelihoods of smallholder farmers. Crop production is estimated to account for roughly 70 percent of typical incomes, of which grain crops account for about 37 percent, on average. Recorded production amounts to 112 million tons per year, although records for some crops and some countries are not available. Most grains are produced and consumed by small farming households.

Significant volumes of grain in developing countries are lost after harvest, aggravating hunger and resulting in expensive inputs—such as fertilizer, irrigation water, and human labor—being wasted. During postharvest operations, there may be losses of both cereal quantity and quality. Qualitative PHL can lead to a loss in market opportunity and nutritional value; under certain conditions, these may pose a serious health hazard if linked to consumption of aflatoxin-contaminated grain. The causes of loss are many and varied. *Technical causes* may include harvesting methods; handling procedures; drying techniques and moisture levels; types of storage or lack thereof; filth or contamination; attacks by rats, birds, and other pests; insect damage; and infestation by food-borne pathogens. *Governance-related causes* can include poor sales, procurement, storage, marketing and distribution policies or practices; absence of mechanisms for dealing with cash flow needs (such as warehouse receipts systems, or WRS); mismanagement or malfeasance in handling grain stocks and associated financing; or difficulty in dealing with the ownership, control, and payment aspects of grain storage and price stabilization programs. Overall, food losses contribute to high food prices by removing part of the food supply from the market. They also have an impact on environmental and climate change, as land, water, and non-renewable resources such as fertilizer and energy are used to produce, process, handle, and transport food that no one consumes.

How large are the PHL for grains in SSA? As mentioned, losses can be physical (i.e., volume shrinkage or deterioration of condition), nutritional (notably, grain contaminated with aflatoxin), monetary (i.e., change in unit sales value), or economic (i.e., not being able to access certain markets). According to estimates provided by the African Postharvest Losses Information System (APHLIS),¹ physical grain losses (prior to processing) can range from 10 to 20 percent. Typically, the magnitude and location of PHL assessments are based on ad-hoc measurements resulting in wide ranges. The APHLIS information platform draws in PHL estimates from national researchers that are well below the 40–50 percent frequently cited in the development community. However, they are still too high to ignore; and in Eastern and Southern Africa alone, based on APHLIS estimates, they are valued at US\$1.6 billion per year, or about 13.5 percent of the total value of grain production (US\$11 billion). There are no similar regional weight loss estimates available for

1 The Postharvest Losses Information System was created within the framework of the project “Postharvest Losses Database for Food Balance Sheet Operations.” This was financed by the European Commission within the work program of its Joint Research Centre (Italy) and implemented by a consortium led by the Natural Resources Institute (United Kingdom) and including ISICAD/BLE (Germany), ASARECA, and SADC/FANR; national experts contributed through the PHL network.

grains in Central or West Africa except for anecdotal estimates. However, assuming losses of a similar magnitude, *the value of PHL losses in SSA could potentially reach nearly US\$4 billion a year out of an estimated annual value of grain production of US\$27 billion (estimated average annual value of production for 2005–07).*

PHL reduction complements efforts to enhance food security through improved farm-level productivity, thus tending to benefit producers and, more specifically, the rural poor. While the cost of loss reduction needs to be evaluated, it is likely that promoting food security through PHL reduction can be more cost effective and environmentally sustainable than a corresponding increase in production, especially in the current era of high food prices. Assuming only a 1 percent reduction in PHL, annual gains of US\$40 million are possible, with producers as a key beneficiary. Viewed in a different perspective, the annual value loss estimate of US\$4 billion (i) exceeds the value of total food aid SSA received over the last decade²; (ii) equates to the annual value of cereal imports of SSA, which had an annual range of between US\$3–7 billion over the 2000–07 period; and (iii) is equivalent to the annual caloric requirement of at least 48 million people (at 2,500 kcal per person per day).

Supply chain efficiencies can achieve PHL reductions, which generate income, improve product quality and safety, and contribute to food and nutritional security. It is against this background that improvements in postharvest handling could increase food security and the livelihoods of rural poor while simultaneously raising the supply and quality of grains to the rapidly increasing urban consumers and potential export markets. Therefore, cost-effective as well as sustainable strategies to promote food and nutritional security need to include PHL reduction as a critical component of on-farm productivity.

OPTIONS TO REDUCE PHL ARE AVAILABLE, BUT THEIR ADOPTION IN AFRICA REMAINS LOW

There are many examples of promising practices. These range from training in improved handling and storage hygiene to the use of hermetically sealed bags and household metallic silos, and are supported by enhancing the technical capabilities of local tinsmiths in silo construction, as described in Chapter 3. The silos can protect the stored grain from pests, rodents, birds, and fungi and, with proper postharvest management, allow it to be kept for long periods with no appreciable loss of quality. Provision of revolving funds and loans facilitate the diffusion of better storage containers. Other interventions involve the establishment of innovative institutional arrangements such as warehouse receipt systems. The choice of technology package depends on circumstances, such as the scale of production, crop type, and prevailing climatic conditions, as well as the willingness to pay (which is linked to social, cultural and economic implications of adoption). In summary, there is a wide range of technologies available that, if adopted, would enable smallholders and larger producers to improve the quality and quantity of grains during postharvest handling and storage.

Government and donor interventions have promoted many technologies in Africa. Traditionally, reduction of losses has been seen as a stand-alone intervention aimed at enhancing household food security. This *technology push approach* dominated PHL-related activities in the 1970s and 1980s. It focused on addressing constraints through the introduction of the particular technology or marketing arrangement considered most appropriate for the needs of a target group in which significant gains in PHL reduction could be achieved. Good recent examples of this type of approach have been the triple bagging of cowpea, which is the subject of a current intensive campaign in West and Central Africa, and the community cereal banks that have developed in recent years. Further evidence of the technology push approach comes from the Kapchorwa district of Uganda, where the timing of the harvests and rainy seasons prompted the introduction of mechanized harvesting and cleaning equipment to reduce losses for wheat and maize.

During the mid-1990s, market-oriented approaches emerged focusing strongly on the market as the driving force for post-harvest improvements, basing their success on good business practice and on facilitating farmer linkages to markets. The promotion of specific technologies has often been complemented by technical assistance on improved farm management within the broader postharvest system. This approach often focuses on on-farm improvements through the establishment

2 Estimated at US\$6.1 billion over the 1998–2008 period.

of PHL baselines, followed by the provision of technical assistance and the transfer of a package of improved technologies and practices along different production and processing steps (e.g., sorting, drying, pest control, farm storage). This “system approach” to tackling postharvest issues emphasizes the links of on-farm activities with other operations within the food and commodity chain, while placing the chain within the wider socioeconomic, business, and political context. Under this approach, value chain coordination is a clear component of the support.

Success stories in Africa, however, have been rare. As discussed in Chapter 4, success is often related to technological transfers from Asia in the context of labor constraints and higher rural wages. Examples of these technologies include small-scale rice dryers, rice threshers, and new bagging techniques. Successful interventions for more traditional grains, such as maize, sorghum, and millet, are more difficult to find. The reasons technologies have failed to be adopted relate to investments that (i) are shown to be financially unsustainable; (ii) have misidentified the key constraints such as focusing on enhancing storage while the economic incentives are missing; (iii) lack cultural acceptability (e.g., introduction of silos where local populations prefer to keep stocks in their homes); and (iv) assume that facilitating change can occur over a short period of time, such as a three-year project.

It has been observed that the same intervention can vary in success rates depending on prevailing circumstances. For example, metal silos have been a notable success in Central America but have not yet been as successful in Africa. This may be attributable to a lack of time to allow impact or to different socioeconomic and cultural circumstances. It is a relatively easy matter to establish the cost and benefits of technologies aimed at the farm or village level, but it is equally important to establish their cultural acceptability. Lessons learned in particular cases such as the metal silos can be generalized and should be taken into account for other technologies. To achieve successful adoption, incentive structures for the immediate beneficiary and the wider community must be in place, learning alliances (LAs) should be created to ensure the interactions of a diversity of key players (effectively the actors of the value chain), and socio-cultural issues should be carefully considered, especially those related to gender and diversity. This combines to highlight the need to evaluate all interventions from a technical, economic, and social perspective if they are to be successfully adopted. The socioeconomic components of postharvest projects should not be small, underfunded afterthoughts, but key drivers.

IDENTIFYING OPTIMAL INTERVENTIONS: USING THE VALUE CHAIN LENS

It is clear that adoption of improved postharvest practices and technologies needs to be better understood from the economic, technical, and social perspectives. *Why do farmers “tolerate” PHL?* PHL are generally tolerated because of a lack of economic incentive to reduce them. Mechanization, unless labor is in short supply, is expensive. Under existing policy distortions, poor access to finance, inadequate connectivity and access to electricity, and the lack of market opportunity mean that the costs of most technologies exceed short-term benefits. Cases presented here indicate that social/cultural factors also matter.

Most of the prior attempts to reduce PHL have focused on the farm level. The more recent emphasis on *market-oriented approaches* and on “linking farmers to markets” has been fundamental for understanding the constraints and lack of incentives for postharvest improvements. These experiences have led to an improved understanding of the critical entry points for PHL reduction along the chain, the interactions between players within the chain, and the impact of the external environment.

Recognizing the failures of the previous attempts, recent interventions increasingly follow the *value chain approach*. Demand for better-quality grain in SSA has been rare, and in most cases, the market has not rewarded the efforts made by farmers and other actors to improve quality and reduce losses. However, several key trends are reversing this situation. For example, widespread urbanization, emergence of a more affluent middle class, changing consumer preferences in the grain sector (including the desire for more convenient foods such as milled maize), and the increased preference for wheat- and rice-based products over traditional grains are some of the key factors driving the development of more efficient and quality-conscious postharvest systems and value chains in SSA. The emergence of institutional, quality-conscious buyers such as the World Food Programme (WFP) has also created a demand for high-quality grain and provided an important market opportunity for farmers who can meet the required standards of quality, quantity, and consistency.

As a result of the issues above, the donor community clearly recognizes the importance of focusing on systemic interventions that improve the efficiency of the chain as a whole, rather than on the disjointed, single-point interventions of the past. They

increasingly use the value chain approach, which is the analytical tool used to better understand flows of product, information, and finance along productive chains; to grasp how direct and indirect economic actors interact; and to identify the most promising points of intervention. Thus, although improvements in postharvest systems at the farm level continue to be a critical entry point, the transition to market-driven systems and greater reliance on the private sector necessitate that PHL interventions be embedded within the context of value chains and that they leverage their success from building synergies with the private sector. To ensure that improvements in postharvest systems are sustainable, PHL reduction strategies that provide economic incentives to key actors in the chain must be developed.

Market-oriented public and donor interventions should involve the private sector. Within value chains, the successful adoption of technologies by smallholders is likely to be influenced by the adoption of other innovations by private sector players farther down the chain. The role of the private sector in improving chain efficiency is therefore critical, as its investment will ultimately result in increased profitability for all chain actors. In recent years, numerous innovative marketing arrangements have involved the private sector, all with the potential to benefit smallholders. These include the establishment of WRS, integrated grain-handling models, and the formation of national and regional trade associations that provide a range of services to their members, including training in postharvest handling, input supplies, and support to collective marketing. Most of these innovations are in the early stages of development, and results have been mixed. Nonetheless, the concepts show promise and are aligned with the market-oriented value chain approach, which has been recognized as a sustainable model for postharvest development. In this regard, they merit further development and testing.

THE PUBLIC SECTOR HAS AN IMPORTANT ROLE TO PLAY

Despite the growing influence of the private sector, the role of the public sector in promoting the uptake of PHL-reducing technologies is essential. The private sector's efforts to develop improved postharvest systems need to be underpinned by an environment that encourages private sector investment. *It begins with the improvement of the enabling public environment and provision of basic public goods such as electricity and roads, which would not only make technologies affordable but potentially shift on-farm activities for PHL reduction to other value chain players.* Improved access to markets, for example, would accelerate trade, thereby reducing the need to store grain on farms and also reducing losses. A predictable price policy would support investments in off-farm storage, potentially providing drying and storage services to smallholders at affordable fees and unleashing the underutilized power of the private sector to provide many PHL solutions. Overall, basic critical factors include a predictable policy and price environment, better roads and lower transport costs, better access to electricity to allow local drying and processing, and improved access to rural finance, among others.

The PHL agenda should be better integrated into *agricultural research and extension services* to provide technical advice and affordable solutions to farmers and private sector players. For smallholders with few options to invest in improved postharvest practices and technologies, the simplest option—and one with only minor financial implications—is improvement in basic storage hygiene and good storage management. The principles of this are well known to experts but are very often not applied by farmers. The research-extension cycle needs to be reinforced to enable extension officers and farmers to access updated information on postharvest management and technologies and to provide feedback to research. A strong research extension cycle creates improved opportunities for technology adoption and postharvest improvement. Research is also needed to understand the constraints to postharvest improvements and to find more effective options for addressing them, including the options for adaptation to climate change.

Investments in research aimed at the identification of cost-effective drying methods and business models to support their adoption, as well as on promising options to replace chemical insecticides during storage, can yield significant gains in terms of PHL reduction at the farm level. Proper drying is a critical control point for minimizing the likelihood of high PHL, but it cannot be achieved with proper management practices alone.

The increased emphasis on competitive, market-oriented systems requires that farmers not only improve their technical skills, but that they also be better organized, act collectively, and acquire stronger group business and marketing skills in order to participate effectively in the value chain context. Thus *technical training* must be accompanied by the development of business management and entrepreneurial skills.

The weak focus on postharvest improvement at the national level is aggravated by its poor representation in the *curricula for agricultural education and in agricultural policy*. There is a need to increase awareness of the benefits of postharvest improvements at the farmer, private sector, and policy levels and to build the capacity to enable the achievement of such improvements. This can be done through (i) inclusion of postharvest modules in the curriculum of agricultural colleges; (ii) building farmer and private sector capacity through informal as well as formal training and information channels; and (iii) harnessing the power of the media—radio, newspaper, television, and video. Implementation of postharvest innovations should be guided by LAs that enable a broad spectrum of public and private sector stakeholders to jointly identify, share, and adapt good practices and solve key problems.

Regarding the issue of providing *direct support to farmers*, some PHL interventions can be subsidized for net-deficit grain producers in food-insecure communities, provided that such interventions are shown to be demand driven, appropriate to their needs, and able to reduce the requirements for food purchase or food aid. It is clear that many SSA grain producers at the lower poverty levels are likely to remain excluded from markets. Thus, the most appropriate attention to these farmers may be that of using subsidized social “safety net” interventions rather than value chain or commercialization initiatives. However, from a food security perspective, the benefits recouped from postharvest improvements among this segment of producers can be significant. To achieve these benefits, the establishment of proper baselines and critical points for postharvest reduction is fundamental. After that, appropriate loss reduction strategies can be applied.

For net-surplus grain producers who are not food insecure, PHL interventions should be introduced without subsidy, as sustainability can be expected from improved market income. Subsidies could be provided in the early stages to demonstrate benefits, encourage replicability, and provide incentives to early adapters. Single-point interventions are probably less effective than coordinated interventions in the whole-value chain (see Table S.1). Interventions that increase the value of the chain and benefit market actors will stand a good chance of adoption, and matching grants and financial incentives to early adopters have been demonstrated as effective tools to ensure sustainability of investments. Within the context of commercialization initiatives, approaches to PHL reduction require an analysis of the whole value chain to determine the most appropriate interventions and their potential effects; they also require the incorporation of strategies to promote coordination, collaboration, and information flow along the chain.

Intervention must be undertaken with consideration of its development objectives—in particular, increasing incomes and enhancing food security. The two objectives are not necessarily mutually exclusive; however, income enhancement is broadly applicable to smallholders who are net surplus producers, while the food security objective is of priority for producers who normally have a net deficit or whose incomes are so low as to render them food insecure. Approaches are outlined in table S.1 and can include specific technology/institutional push interventions targeted at farm operations with some degree of subsidy involved. Exit strategies should be envisioned, but economic sustainability need not be a priority consideration.

Measuring success should be a strong component of interventions aimed at optimizing postharvest systems. Increasingly, donors want to understand the contribution and effect of their investments, and it is clear that the identification of common sets of indicators that support the comparison of PHL results (in terms of reduction of losses and sustainability) remains an unmet need. This requires much greater thought and research into the relationship between inputs/activities, outputs/outcomes, and effects. Measurement of process as well as product is required, which means identifying suitable indicators for both. With a few exceptions, the postharvest grain interventions reviewed have not had elaborate baseline surveys, did not set themselves impact indicators, and have not had ex-post evaluations. This paucity of data on impact makes comparison of interventions very challenging. Clearly, future interventions need to correct this deficiency.

At the international level, there is currently no recognized coordinating mechanism for the further development of PHL technologies and adaptive strategies for grain production. Development practitioners, national policy makers, and other professionals and analysts promoting agriculture-related improvements need to start thinking in terms of optimizing postharvest systems, with both food security and income enhancement objectives. A set of international development partners and organizations, along with private sector representatives, have achieved agreement regarding the importance of revitalizing a *postharvest community of practice*. This practice is aimed at facilitating the evaluation of innovations, assisting in their scale-up, and supporting knowledge and information sharing on best practices and lessons learned. Such a community would allow the channeling of expert knowledge into the development agenda and would

inform investment programs. It will also be an essential contribution to reversing the trend of declining postharvest expertise and increasing activity within the sector.

Understanding the magnitude of the problem can create opportunities to leverage food security and poverty outcomes from PHL reduction strategies. The APhLIS database could be expanded to become an archive of postharvest projects and studies and the counterpart to the FAO INPhO (Information Network on Postharvest Operations) system, which provides information on postharvest technologies for all crops but not data on specific projects. This approach would go a long way toward preserving the institutional memory on postharvest interventions for grain value chains and possibly serve as the foundation of a regional LA that builds bridges between the research and development communities. Yet, beyond this repository function, there are other critical steps to make the PHL data more relevant and useful. These steps include a collective effort to generate consensus on methodological aspects of PHL estimation; strengthening the quality and accuracy of the data collected by APhLIS; and defining of indicators related to grain quality, safety, and economic value to complement physical PHL estimates.

TABLE S.1: Framework for distinguishing the objectives and target groups for future of PHL-reduction interventions

DEVELOPMENT OBJECTIVES FOR SMALLHOLDER PRODUCERS	RELEVANT CROPS	EXAMPLES OF PH INTERVENTIONS	FACILITATION	CONDITIONS
<p>Income enhancement: Livelihood improvement for smallholder producers through more cash income.</p> <p>Achieved by: Reducing economic losses by upgrading value chains (e.g., higher value markets, better quality product). Reducing physical losses by the adoption of improved technologies and approaches by smallholders.</p>	<p>Maize Rice Wheat Barley Sorghum and millet (rarely) Teff (Ethiopia)</p>	<p>To create a safer, better-quality, higher-value product through the adoption of:</p> <ul style="list-style-type: none"> • Improved knowledge and technologies, including mechanization for grains handling, drying, and storage • Market information systems • Creation of marketing groups • Business fairs to link chain actors • Private off-farm storage and, where feasible, WRS • Inventory credit schemes 	<p>Training and education, especially in business skills Credit supplied by microfinance to enable technology adoption Agricultural policy improvements to support markets and the application of grades and standards</p>	<p>Single-point interventions rarely valid. Need coordinated interventions in whole-value chain. Rationale based on commercial advantage and sustainability from financial incentive. Must be shown to improve livelihoods.</p>
<p>Increased food self-sufficiency: A larger and more reliable supply of grains and reduced need for emergency purchases and food aid.</p> <p>Achieved by: Reduced physical losses by the adoption of improved technologies and approaches by smallholders.</p>	<p>Maize Sorghum Millet Teff (and other local crops) Wheat (Ethiopia) Rice (rarely)</p>	<p>To prevent waste and deterioration of the grains produced by smallholders:</p> <ul style="list-style-type: none"> • Zero-cost storage interventions such as improved hygiene and storage through greater knowledge, skills, and awareness. • Low-cost storage interventions, such as tarpaulins to aid in drying maize, hermetic storage using plastic sacks, improvements to traditional stores, and informed and rational use of grain protectants. 	<p>Training and education Subsidy of interventions</p>	<p>Single-point interventions may be valid. Requires an assessment of loss and potential loss reduction before implementation. Rationale based on the contribution to food availability or reducing need for food aid. Must be shown to improve human welfare.</p>

Source: Authors.

1. INTRODUCTION

After a flurry of development effort in the 1970s–1980s, the world seems to have forgotten the importance of PHL in the African grain sector. However, attention is returning to this area with a renewed emphasis on agriculture and food insecurity in SSA. The renewed focus on investment in agriculture that began in 2008 is prompting new interest in effective interventions for PHL reduction, because the investment required to reduce PHL is relatively modest and the return on that investment rises rapidly as the price of the commodity increases. Moreover, the technological advances from the last decade or so make reduction of PHL at the farm and village level more feasible and less expensive than before.

Therefore, PHL are increasingly recognized as a part of the integrated approach to ensuring the full realization of agricultural potential to meet the world's increasing food and energy needs. Reducing PHL, together with making more effective use of today's crops, improving productivity on existing farmland, and sustainably bringing additional acreage into production, are critical in meeting the challenges of feeding an increased world population. As a result, PHL reduction features prominently in the recent global initiatives such as the Comprehensive Framework for Action issued by the UN High-Level Task Force for Food Security and Nutrition after the global food crisis, the Global Agricultural and Food Security Program endorsed by the World Bank in January 2010, the Africa Food Crisis Response of the African Development Bank (AfDB), and the recently reformed Committee on World Food Security (CFS). Attention is drawn to the same issues on the websites of both the Alliance for the Green Revolution in Africa and the New Partnership for Africa's Development.

"Preserving what is already grown is critical to reaching those who need crops most and to making the most of the land, water, energy, and other inputs already used to grow crops."

*Patricia Woertz, chairperson,
CEO, and president of Archer Daniels Midland Company.
January 29, 2010. World Economic Forum.*

Given the importance of grains in production and consumption in SSA, a reduction in grain PHL is an important objective because these losses are not only a waste of valuable food and other resources (agricultural inputs, labor, land, water, etc.) but are also symptoms of poorly performing value chains. Such poor performance is a cost to the poorest in that it constrains the livelihoods of those engaged in agriculture and limits the success of agricultural economies.

Past efforts to reduce PHL have been intermittent. As a result of the food crisis of the 1970s, the international community focused some development effort on postharvest activities, including reducing grain losses. This led to the creation of a coordinating body, centered around donor representatives in the Group for Assistance on Systems Relating to Grain After-Harvest (GASGA). This group was involved in various efforts to reduce PHL, the largest of which was the "Prevention of Food Losses" program of the 1980s–90s, under the auspices of the UN FAO. An Indian-led initiative, the Save Grain Campaign, was launched at about the same time. As the food crisis waned, and as approaches to food security refocused on economic liberalization and trade, GASGA's scope was expanded beyond grain to other agricultural commodities and was renamed the Global Postharvest Forum (PhAction), but even this grouping was gradually eroded (Box 1.1). The final effort of PhAction was to recognize the importance of the market in agricultural development with a drive to create a CGIAR Challenge Program on "Linking Farmers to Markets." However, as the priorities of the international community moved away from agriculture, PhAction fell into abeyance in the early 2000s.

The surge in food prices in 2007–08 heightened concerns over food supply, especially the risks of intermittent food shortages in the distant future. This situation presents a threat to food security, but it also offers opportunities for agricultural economies to benefit from higher food prices and increased demand. The recent food crisis calls for further action against PHL, but this time markets are substantially liberalized and thus require careful public actions to help the

BOX 1.1. Coordinating bodies for grains postharvest development

PhAction (Global Postharvest Forum) was formerly the Group for Assistance on Systems relating to Grain after Harvest (GASGA). The aims and priorities of GASGA evolved considerably over its lifetime (1971–99). From an initial focus on the provision of coordinated technology transfer in grain storage in Africa, it was ultimately concerned with analysis of postharvest systems for food crops throughout the developing world and the impact of these systems on food security, food quality, and value-addition as a contribution to rural livelihoods. It was agreed at the 1999 annual meeting that GASGA had served its purpose well and had adapted to a changing world by rethinking its views and priorities. However, it was also agreed that it was time to launch a new initiative on the basis of these new approaches, with an enlarged membership and an ambition to form a more inclusive global forum for postharvest issues, supported by parallel information-resource developments in the INPhO web-based databank. Therefore, GASGA was dissolved and PhAction was initiated, with ten members, including four national bodies, FAO, and five CGIAR centers. The role of PhAction was to raise the profile of postharvest research and development and to accomplish greater impact in the postharvest sector.

Source: FAO.

private sector respond to the market opportunity, rather than crowd it out.

This requires a move from a supply driven approach to an entrepreneurial- and market-oriented approach. However, there is a continuing need for public investment in promotional

BOX 1.2. The key role of economic incentives in PHL reduction

In the current environment, greater and more sustainable benefits can be obtained if interventions to reduce PHL are considered within the context of commodity and value chains, the central role of the private sector, and profitability of loss-reducing interventions. Economic incentives are likely to play a very significant part in reducing PHL. Care for grain, willingness to produce grain of better quality, and, hence, willingness to pay for improved postharvest approaches all depend on favorable economic returns.

Source: Authors.

activities that entrepreneurs cannot be expected to subsidize individually. Furthermore, there remains a need for all interventions to be carefully evaluated from a technical, economic, and social perspective and to be adapted as necessary if they are to succeed (Box 1.2).

In light of the above challenges and opportunities, this report takes stock of the current state of knowledge and technology with respect to the on-farm and community-level postharvest handling and storing grains, with a view to raise the profile of PHL and to provide policy recommendations. This activity also aims to help revive and invigorate a theme and body of knowledge and to stimulate greater coordination and collaboration between the World Bank, AfDB, FAO, the International Fund for Agricultural Development (IFAD), the European Union Delegation (EU), and possibly other interested donors or regional development banks.

This report is based on the desk study undertaken by experts of the U.K. Natural Resources Institute (NRI). Data were collected by direct contact (e-mail or telephone), with authorities holding information on past and current projects; by searching the Internet for details about projects; and by reviewing published and “gray” literature. Data were also collected from the personal experiences of the NRI review team who had worked on numerous and diverse projects to reduce grain PHL in SSA over the last 30 years and from experts in the field. These experts were identified and asked to complete a questionnaire that would draw out their experiences to indicate the weakest links in the postharvest chain, the interventions that deserve to be prioritized for future action, and those that should be avoided. Of about 40 invited respondents, a total of 20 returned completed (or partially completed) questionnaires. The grain postharvest field is relatively small and multidisciplinary. Numbers of technical experts have fallen sharply since the 1990s owing to the shift away from agriculture as a priority for aid donors. Consequently, the number of individuals available for consultation about this, especially with reference to SSA, is quite small.

The team’s different approaches to gathering data met with varying success. Direct contact with institutions and individuals provided only a few—but very rewarding—sources of information. Using institutional public access e-mail addresses to request information on projects was almost universally a failure. Approaching named individuals had about a 30 percent success rate, and seeking detailed reports on past projects from these individuals yielded relatively little beyond what was already available on the Internet. Our conclusion

was that the documentation of postharvest projects and related institutional memory is weak.

Only a few Web sites offer access to data on postharvest grain projects; FAO's information network on postharvest operations offers a lot of technical information but little data on projects. The most diverse and informative site is Research into Use (<http://www.researchintouse.com>), which yields information on a host of projects of the Crop Postharvest Program of the United Kingdom's Department of International Development (DFID) as well as DFID's Research for Development portal (<http://www.research4development.info>). Even more detailed, but of narrower scope, is the PostCosecha Web site, supported by the Swiss Agency for International Development Cooperation, which presents their work with metal silos in Central America. The Web site of the International Development and Research

Centre of Canada offers downloads of some of their reports (now rather old, as their postharvest programs ended in the 1990s), and the IFAD Web site offers a good way to locate current projects.

The report consists of five chapters. Chapter 2 considers the importance of grain production in SSA, describing typical postharvest handling and marketing stages, stating the nature of PHL, presenting the available estimates, and discussing the problems of PHL estimation. Chapter 3 discusses the options available to reduce PHL and achieve better adoption of technologies in SSA, and it analyzes the reasons for low adoption of PHL-reducing technologies. Chapter 4 looks at the evolution of government and donor approaches and identifies areas for future interventions, informed by the questionnaire survey of postharvest experts. The way forward for PHL reduction is presented in Chapter 5.

2. NATURE AND MAGNITUDE OF PHL FOR GRAINS IN SUB-SAHARAN AFRICA

THE SOCIOECONOMIC IMPORTANCE OF GRAINS IN SSA

Grains are the most important food staple in SSA. They are the predominant crops, except in certain areas of West and Central Africa, where the populations rely on roots and tubers or plantains. Hence, this report focuses on grains. Maize, mostly white varieties, is the most widely planted crop in the region and has the highest production (Figure 2.1). Maize is grown in all but very dry agro-ecological zones, where sorghum and pearl/bulrush millet are dominant. Rice cultivation is widespread and increasing in response to changing patterns of local consumer demand, and wheat and barley are grown in areas that are more temperate or under irrigation. Some indigenous grains, particularly teff and fonio, are important locally. Total annual grain production is in excess of 112 million tons.

The traditional grain crops in Africa are millet and sorghum, and these grains are cultivated throughout the drier parts of SSA. Both crops tend to have lower yields than maize (and usually only a single annual harvest). They are, however, important food-security grains because of their relative drought tolerance. Nearly all millet in Africa is of the bulrush/pearl type, rather than finger. On the plant, millet and sorghum grains are exposed on panicles that suffer considerable loss from pests in the field—particularly birds—but they are usually harvested very dry and are therefore relatively resistant to postharvest pest attacks. When placed in good storage, even without any insecticide treatment, small-grained millet can be kept for two or three years with relatively little damage (e.g., in Namibia).

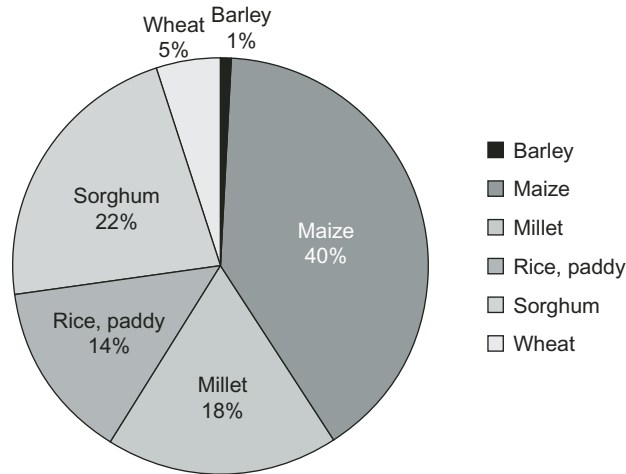
Maize was introduced into Africa by Portuguese traders in the 15th century, and for a long time it was grown as a vegetable crop; the cobs were picked and eaten while still moist. The crop is an important component of the diet in some countries; in Kenya and Tanzania, for example, maize contributes about 34–36 percent of the daily caloric intake. Only in the more recent past have maize grains been treated like the more traditional grain crops. Millet and sorghum,

after being fully dried, are stored, either on the cob or as shelled grain, and then milled into flour. The advantage of maize over millet and sorghum is its relatively high yield and resistance to pest attacks in the field, as the grains are fixed on a cob that is usually covered by a tight sheath. Maize is widely preferred by African consumers and is replacing millet and sorghum in many parts, even where the climate is only marginal for this crop. Commercial maize farming has led to the development of high-yielding varieties; the first of these were from Zimbabwe, where several “SR” varieties were very successful. They have had the disadvantage of requiring other agricultural inputs, however, and often have greater susceptibility to pest attacks both pre-harvest, due to incomplete sheath cover, and post-harvest, due to softer, more easily eaten grain. There are many local and improved varieties. Most smallholders grow mixtures of local and improved varieties in their fields, although some do grow high-yielding hybrid maize (especially in southern Africa). Very often these crops are sold soon after harvest, both to avoid losses in storage and because farmers are in urgent need of cash after the harvest.

The recent commercial introduction of genetically modified white maize varieties with, for example, resistance to herbicide has caused much policy debate (Hilbeck and Andow 2004). This started in South Africa but is now also in Kenya. Some countries have accepted this new technology as an opportunity for smallholders to reduce labor and input costs, while others, such as Zambia, believe that the new technology threatens their domestic biodiversity. Not much is known about the impact of genetically modified maize on storage, postharvest handling, and biodiversity outcomes.

Rice farming was traditionally confined to the cultivation of African rice in marshy places, although planting of Asian long-grain rice has been a longstanding practice in Madagascar, owing to its links with Indonesia. More modern rice cultivation of long-grain Asian rice was introduced into mainland Africa in the 20th century, especially in the Niger delta in Mali and other damp places in West Africa. The very strong local

FIGURE 2.1. Structure of total grain production of 112 million tons in SSA

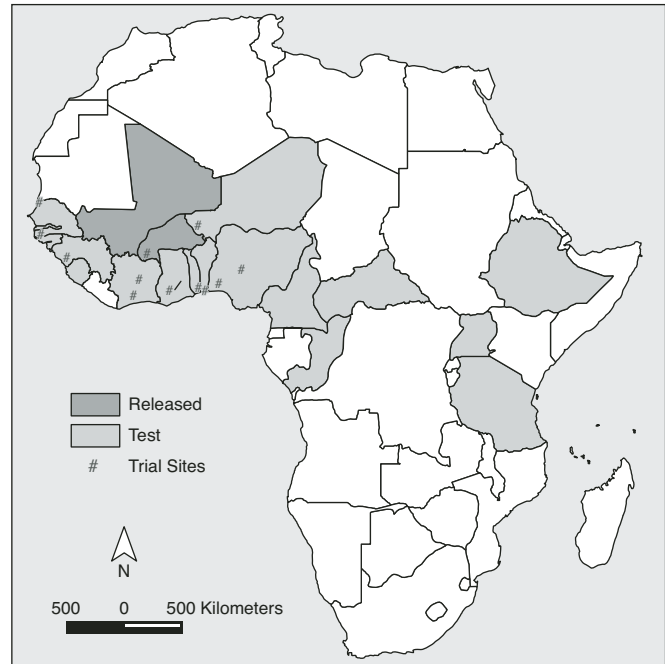


Source: Based on data from FAOSTAT (2008).

demand for rice and desire for import substitution has been a stimulus for the development of more effective rice cultivation. The last 10 years have seen considerable commercial development of rice, especially of outgrower schemes supported by rice millers (e.g., Tilda in Eastern Uganda). A further important development has been the creation of the New Rice for Africa (NERICA), a cross between African and Asian long-grain rice, which has the lower water requirements of upland rice and has therefore brought higher yields to many parts where irrigation is not feasible. However, it is also beginning to spread widely to the irrigated areas (Figure 2.2). An important characteristic of the rice subsector in SSA is the large quantity of imports. FAO statistics¹ show that SSA, while producing only 1 percent of global rice, accounted in 2009 for an estimated 33 percent of global imports of rice with nearly two-thirds bound for West African markets. In comparison to locally produced rice, imported rice is of a better consistency in terms of size, variety, color, and cleanliness. It is also easier to prepare—a characteristic which is particularly important in the urban areas, where consumers value convenience due to busy work schedules. Domestic rice, by contrast, tends to be characterized by high levels of foreign matter such as stones, broken kernels, mixed varieties, and an unattractive color (parboiled and unpolished).

Teff and fonio are small cereal crops. The production of teff is confined to Ethiopia and Eritrea, and postharvest problems are limited, as grains are too small for insects to attack. Teff has potential for expansion and in recent years has become an important export crop in Ethiopia, to the extent that the

FIGURE 2.2. Countries in SSA where irrigated lowland NERICA varieties have been released or are being tested



Source: Somado et al. (2008).

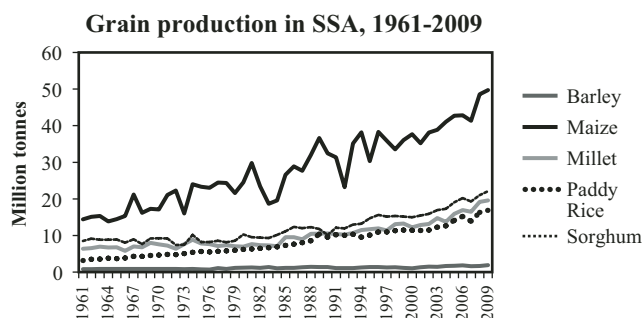
domestic price has risen. Fonio is a wild-grown crop and is often harvested when other crops fail.

Not all grains are for food. Grains are used in the production of local beer, which has an important socio-cultural role in many African societies and is an important income earner for women. Grain by-products are also a source of fodder in many countries, and the dried stems of the plants may be used as housing material and cooking fuel.

In SSA, grains are supplied from domestic production, commercial importation, and food aid. Imports have grown in importance as a source of supply over the years. The share of imports in total grain consumption increased from about 5 percent in 1961 to over 25 percent in recent years. Food aid increased sharply in the 1980s, reaching more than 10 percent of total grain consumption in 1984 (FAO 2006). Although the importance of food aid has declined since then, it still accounts for between 3–5 percent of the total grain consumption in SSA. Production of the major grains in SSA has been rising at 3 percent annually over the past 40 years (Figure 2.3). Table 2.1 presents detailed production data by region.

SSA countries were occasional net grain exporters in the early years after the 1960s, shipping small volumes of maize and sorghum. At that time, grain imports represented only

¹ Food Outlook, Global Market Analysis, FAO, June 2010.

FIGURE 2.3. Grain production in SSA, 1961–2008, million tons

Source: FAOSTAT.

1 percent of total consumption. FAOSTAT data show that SSA grain imports grew sharply, starting in the early 1980s, to 24 million tons in 2007, valued at US\$7 billion and accounting for 26 percent of total grain consumption. Net imports are estimated to have increased more than fourfold over the past two decades, from an average of 5 million tons in 1990s to 23 million in 2007 period. When North Africa is included, net imports rise to 48 million tons. Wheat accounted for about half of grain imports throughout the last 40 years, and rice about one third. Maize, which was an occasional export commodity in the 1960s, now represents about 15 percent of grain imports.

Food represents about 10–20 percent of consumer spending in developed countries and as much as 60–80 percent in developing countries; in SSA, household spending on food constitutes more than 60 percent of income. Crop production remains the principal source of income for households in SSA—roughly 70 percent on average, of which grain crops (predominantly maize, sorghum, millet, and rice) account for about 37 percent of total household income, while non-crop income averages about 30 percent of total income (Table 2.2). This proportion is close to the figure reported by Reardon

et al. (1992; 1997) for West African countries—26 percent. Much of a household’s non-crop income comes from live-stock, mainly cattle. Cash-oriented, nonfarm activities provide only 6 percent of total household income per capita. Thus, diversification across activities might seem to be a sensible strategy in reducing income variability.

THE POSTHARVEST SYSTEM FOR GRAINS IN SSA AND THE NATURE OF THE LOSSES

The postharvest (postproduction) and marketing system is a chain of interconnected activities from the time of harvest to the delivery of the food to the consumer, often referred to as “farm to fork” (Figure 2.4). Within this farm-to-fork continuum, a set of functions are performed. In grain value chains, examples of functions include: harvesting, assembling, drying, threshing/shelling, milling, storage, packaging, transportation, and marketing. However, the efficiency by which those functions are performed depends on the specific context including not only economic, social (e.g., cultural aspects, gender), technical, and business considerations, but also wider considerations related to the overall enabling environment, including availability of facilitating services and infrastructure, strong institutions, and macroeconomic aspects.

From a functional point of view, the primary role of an effective postharvest system is ensuring that the harvested product reaches the consumer, while fulfilling market/consumer expectations in terms of volume, quality, and other product and transaction attributes, including nutrition, food security, and product safety. Once harvested, products are subject to biological deterioration, but the rate of deterioration is highly influenced by factors and practices that increase product exposure along the chain to extreme temperatures, excessive rain, contamination by microorganisms, mechanical damage,

TABLE 2.1. Indicators of grain production and imports in Africa

REGIONS	ANNUAL GROWTH RATE OF GRAIN PRODUCTION (%)		NET IMPORTS (IMPORTS-EXPORTS) (1,000 TONS)		IMPORTS AS A SHARE OF CONSUMPTION (%)	
	1961–1990	1991–2007	1970S	2000–2007	1970S	2000–2007
World	2.8	1.1	—	—	—	—
Africa	2.4	1.3	9,235	47,642	18	30
East Africa	2.1	2.8	531	5,752	7	17
Central Africa	0.7	2.4	742	2,778	24	34
North Africa	3.2	0.8	7,588	27,041	33	47
Southern Africa	1.9	1.6	(2,015)	2,222	6	23
West Africa	2.6	1.9	2,388	9,847	14	20

Source: Authors.

TABLE 2.2. Mean household income shares spent on food in SSA

ENTERPRISE	% OF TOTAL INCOME		
	1994–96	2001–02	2003–04
Crop production (of which)	70.6	69.1	72.5
Grains	37.3	38.3	35.1
Roots and tubers	13.2	14.2	17.7
Beans and oilseeds	7.3	8.3	9.6
Nonfood cash crops	2.0	2.4	5.5
Fruit and vegetables	5.0	5.9	4.6
Other crops	5.2	—	0.1
Animal products	3.4	2.8	5.1
Off-farm activities	26.0	27.7	21.7

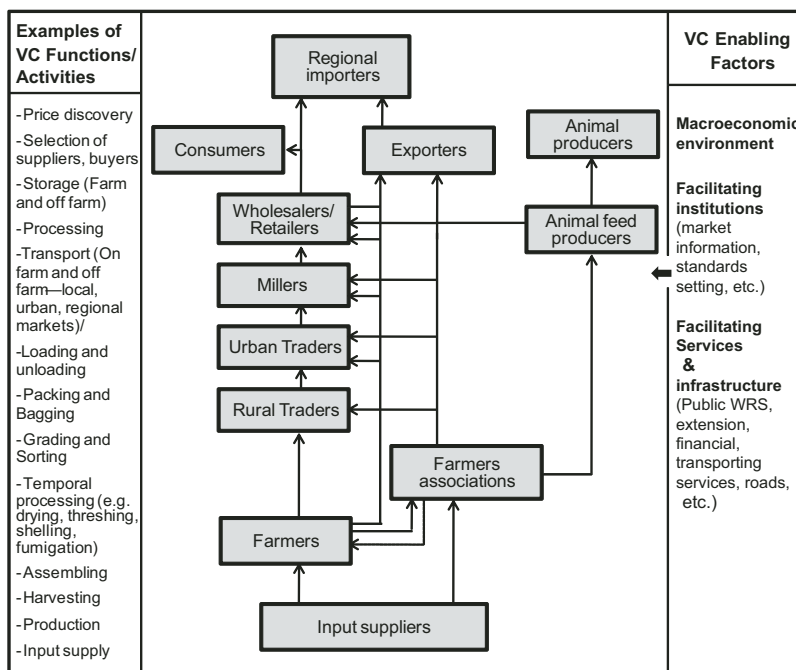
Sources: FAOSTAT; Jayne et al. (2001).

chemical contamination, etc. Therefore, a critical step in minimizing PHL is the understanding of the influence of biological and environmental factors, as well as handling practices on product deterioration and, of postharvest technologies and practices that will slow down the process and maintain quality and safety of the product. Table 2.3 presents examples of the causes of postharvest losses for maize identified by surveyed (small, medium, and large) farmers in Kenya, Uganda, and Tanzania in 2008.

While the causes of the PHL are manifold and can occur at any stage between harvest and consumption, PHL can greatly be influenced by production conditions (pre-harvest stages). For example, end-of-season drought and mechanical damage to pods during pre-harvest are important factors contributing to aflatoxin contamination and subsequent mold growth during postharvest stages.

PHL can be quantitative (e.g., physical weight losses) and qualitative (e.g., loss in edibility, nutritional quality, caloric value, consumer acceptability, etc.). Others refer instead to *direct* and *indirect* losses. Direct losses are related to the total or partial loss of product resulting from spoilage caused by mechanical, physical, physiological, or biological damage; indirect losses relate to qualitative loss. Others use the term *opportunity losses* to refer to losses resulting in lost sales or sales only made in low-value markets due to quality problems and other market constraints (Box 2.1). *External losses are an additional category*. These fall on both the value-chain participants and society as a whole—for example, cases in which the chemical pesticides used to protect grain impact the environment or human health. External losses can be difficult to estimate in economic terms (see Lubulwa et al. (1995) for an example of cassava cyanide).

The following pages present a brief characterization of the ways some of the postharvest related functions are performed in grain chains in SSA, highlighting the different factors that can influence postharvest losses along the different chain stages.

FIGURE 2.4. Illustration of a generic value chain for maize

Source: Luz Diaz Rios.

TABLE 2.3. Causes of PHL (in percent to total losses)

CAUSES OF LOSSES	KENYA			UGANDA		TANZANIA	
	SMALL	MEDIUM	LARGE	SMALL	MEDIUM	SMALL	LARGE
Losses due to transporting on poor roads	0	5		11	6	13	
Lack of storage	6	0		18	13	13	13
Pest infestation	17	18	37	25	32	40	50
Poor quality of storage facilities	28	14		20	16	23	25
Impact of weather	33	58	50	29	28	10	13
Spillage	17	5	13	4	6		
Total	100	100	100	100	100	100	100

Source: World Bank 2009.

HARVESTING

Most grains have a single annual harvesting season, although in bimodal rainfall areas there may be two harvests of maize or rice (e.g., Ghana and Uganda). African producers harvest grain crops once the grain reaches physiological maturity (moisture content is 20–30 percent). At this stage the grain is very susceptible to pest attacks. Also, unseasonal rains at this stage can dampen the crop, resulting in mold growth and the associated risk of aflatoxin or other mycotoxin contamination. Weather conditions at the time of harvest are a critical factor influencing PHL. More unstable weather conditions due to climate change, leading to damper or cloudier conditions, may therefore increase PHL. However, this appears to be undocumented. In most part of SSA, harvesting is traditionally the work of men; however, with the rise in single-headed households, the burden between men and women is increasingly shared.

Harvesting by hand is the traditional method used by small producers in Africa. The relatively very few large-scale farmers may use machines to harvest their crop. No data show any difference in PHL between hand and mechanical harvesting for SSA. In principle, hand harvesting is likely to

BOX 2.1. Maize value related to damage

It has been found with maize in Ghana that for every 1 percent damage above 5 percent (damage referring to grains with insect holes), the value decreases by 1 percent. So if undamaged grain is worth US\$1.00/kg, then grain with 10 percent damage is worth only US\$0.95/kg, and with 20 percent damage it is worth only US\$0.85/kg. These potential losses in value can make a substantial difference to a family's livelihood (DFID Crop Postharvest Program).

Source: FAO.

be less wasteful, but labor constraints can lead to delays in or failures to harvest; these, then, can result in significant postharvest losses. This appears to be undocumented.

DRYING

Most farmers in Africa, both small and large, rely almost exclusively on natural drying of crops from a combination of sunshine and movement of atmospheric air through the product, so damp weather at harvest time can be a serious cause of postharvest losses—measured losses in excess of 16 percent in Swaziland (De Lima, 1982). Grains should be dried in such a manner that damage to the grain is minimized and moisture levels are lower than those required to support mold growth during storage (usually below 13–15 percent). This is necessary to prevent further growth of a number of fungal species that may be present on fresh grains. To achieve this, the harvested crop may be left standing in the field, cut and left drying on the ground, or stooked. In some places, the crop may be moved immediately from the field to a swept area of ground at the homestead (Figure 2.5) or to racks or cribs that are specifically designed to promote drying

FIGURE 2.5. Maize drying in the yard



Source: Rick Hodges.

FIGURE 2.6. Maize drying in a crib

Source: Rick Hodges.

(Figure 2.6). Commercial farms may rely on large-scale drying cribs for maize. In the case of rice, the crop may be threshed before it is fully dry and the grain placed on a drying floor to complete the process. However, successful drying alone is not a remedy against all PHL, as insects, rodents, and birds may attack well-dried grain in the field before harvest or may invade drying cribs or stores after harvest.

THRESHING/SHELLING

For some grains, particularly millet and sorghum, threshing may be delayed for several months after harvest and the unthreshed crop stored in open cribs. In the case of maize, the grain may be stored on the cob with or without sheathing leaves for some months, or the cobs may be shelled and grain stored. All grains will eventually be threshed or shelled. For smallholders this is almost exclusively a manual process, except for the few cases in which some groups have access to machinery suitable for small-scale operation, such as the maize shellers that some tractor owners may hire out. Rice postharvest activities particularly benefit from mechanical threshers, which are available through some outgrower schemes and are actively being promoted by International Rice Research Institute (IRRI)/Africa Rice (WARDA) (Annex 2, Project 19).

WINNOW/CLEANING

Winnowing and cleaning of grain is usually done prior to storage or marketing if the grain is to be sold directly. For the majority of smallholder grain, this process is undertaken manually (Figure 2.7). It is relatively ineffective from a commercial perspective, since grain purchased from smallholders frequently requires screening to remove stones, sand, and extraneous organic matter. There is little incentive for smallholders to provide well-cleaned grain for marketing, as

FIGURE 2.7. Winnowing

Source: Rick Hodges.

there is usually no premium for quality; rather, there is every incentive to leave foreign matter in the grain, especially at the bottom of sacks, so that profits from sales can be maximized. Some small-scale equipment is available to farmers' groups to winnow or clean maize and rice.

ON-FARM STORAGE

PHL at storage are associated with both poor storage conditions and lack of storage capacity. It is important that stores be constructed in such a way as to provide (i) dry, well-vented conditions allowing further drying in case of limited opportunities for complete drying prior to storage; (ii) protection from rain and drainage of ground water; and (iii) protection from entry of rodents and birds and minimum temperature fluctuations. Technically speaking, traditional methods of grain storage adopted by smallholders in Africa are usually well-adapted to the prevailing climate. In hot, humid climates, farmers typically use very open storage structures to allow free airflow and continuous drying; at the other extreme, in hot, dry climates, farmers use sealed stores with no airflow

BOX 2.2. Findings of PHL assessment surveys

Preliminary findings from a PHL assessment survey conducted in Malawi by the Ministry of Agriculture and Food Security with technical support from FAO indicate losses in the region of 7–8 percent for cob-stored maize during the 2009–10 storage season. This is consistent with the typical range of maize storage losses described above.

Source: Authors.

FIGURE 2.8. Indoor *Kihenge* (woven granary) and sacks

Source: Rick Hodges.

because the crop enters the store dried. Intermediate climates have stores designed with intermediate airflows. In recent years, there has been rising popularity for storage in jute or polypropylene bags that are stacked in the house. Such bags have an intermediate ventilation rate depending on where they are located in the house. Box 2.3 highlights the trend of increasing bag storage in Tanzania. In fact, this trend is not limited to Tanzania; it is gaining ground across the entire SSA region due to the increasing market orientation of even small farmers as well as the spreading threat of larger grain borer (LGB) infestation. From a social perspective, storage can also have an important social role delineating patronage and power within households and among peers.

With a degree of mechanization, large-scale farms would normally only store grain (rather than maize cobs, unthreshed millet, or sorghum) and this would normally only be in sacks.

BOX 2.3. Increasing use of bag storage in Tanzania

Tanzanian farmers explained that sack storage is becoming increasingly popular, as sacks are more portable in case of emergencies (e.g., floods, fires). They are always ready for marketing in case of need for emergency or opportunistic sales, and they take up less space in the house (their bulk reduces proportionately, as opposed to a large woven granary that fills a whole room, whether empty or full). Skills for constructing the traditional woven and mud-plastered granaries are being lost. When grain is in sacks, it is easier to monitor quality, and sacks can be hidden more securely during times of food insecurity, as they are typically kept in the bedroom.

Source: Authors.

In SSA, bulk handling, including the use of silos, is almost entirely restricted to South Africa with isolated examples elsewhere in southern and eastern Africa (and formerly in Ghana). The pros and cons of bulk handling in developing countries have been considered in detail (Friendship and Compton 1991) and are complex.

PHL in storage vary widely, with variation by crop, variety, climate, storage structure, grain protection options, and length of storage period. Maize as grain or cobs (without LGB infestation) typically undergoes 4–5 percent losses in storage, sorghum grain 2–4 percent, wheat 3–5 percent, millet 1 percent, and rice and teff 1 percent or less.

Teff is an interesting case; it is well known to suffer few losses in storage, as its very small grain size makes it resistant to insect attack. Indeed, in Ethiopia, one way to prevent infestation of maize grain is to admix teff, which fills the intergranular spaces preventing insect pest damage (Haile 2006). The situation with maize is more complex as it may or may not be infested by LGB. If cobs or grains are infested by normal storage pests, not LGB, then weight losses typically range from 4–5 percent. When cobs are infested by LGB, weight losses can more than double (Hodges et al. 1983; Dick 1988; Boxall 2002b) and, if left unchecked, may result in the total destruction of the stored grain. Shelling grain and storing in sacks (as well as addition of insecticide) are the standard recommendations to reduce losses resulting from LGB attack.

To limit subsequent infestation of stored grain by insects, farmers may add materials with insecticidal properties to the grain. These materials can be of local origin, such as plants or inert dusts. A wide range of plant materials have been used with some success in insect control. The efficacy of plant materials is highly variable even within plant species, depending on variety, season, soil types, and the way that the plant material is used (whole dried products, powders, extracts etc.). The products may act as natural insecticides or as repellents. In most cases, their safety to the consumer has not been established; and in many cases, they will taint the grain, limiting its commercial value. Some are known to be toxic. A particular case in point is the use of neem oil extended for the treatment of grain in Benin. The bitter taste of the oil discouraged farmers from applying it, even though the taste could be completely removed when the grain was soaked for a long time in water. An extensive listing of botanical materials that have traditionally been used for the suppression of insect pests of stored crops has been prepared (Dales 1996), and the prospects of using some of them more effectively in stock protection and as alternatives to synthetic pesticides have been researched and remain a possibility (Annex 2, Project 2).

The inert dusts include material such as ash from maize cob cores, paddy husk, sand, or clay that can be admixed with grain to provide a barrier to insect entry. In Cameroon, the use of ash has been extended to farmers for protecting cowpeas, although the same technique could be expected to work for grains. The cowpeas are mixed with an equivalent volume of ash, from which large particles have been sifted (Wolfson et al. 1991; Kitch and Giga 2000). Once the storage vessel has been filled with ash, a further 3-cm layer of ash is added to the top to provide a barrier to pest entry. In the case of ash, there may be a problem with tainting and discoloration, and all these types of admixture are inconvenient in that they require cleaning of grain. Appropriate postharvest management is fundamental for the storage of the grain that is intended to be used as seed for further planting, but for cultural reasons it may be unacceptable to certain groups (Murdock *et al.*, 2003). The most reliable treatments are synthetic insecticides approved for use on grain, especially organophosphorus compounds such as pirimiphos methyl (actellic), fenitrothion, and malathion, usually by admixture of a dilute dust formulation. In the case of protection against the LGB, actellic super is used.

There may be greater absolute PHL during bumper harvests resulting from a sharper fall in market prices (Box 2.4). Low prices and surplus production may result in a slower flow to the market, leading to longer storage periods on the farm. In this situation, there may be an increase in loss due to insect

BOX 2.4. Responding to bumper harvests

High PHL may occur when there are bumper harvests. This also tends to be the time when prices for grains are lowest. Bumper harvests often result in high levels of political pressure to “deal with surplus crops.” Planning for occasional bumper harvests is particularly challenging and has often resulted in overinvestment in village-level stores (e.g., in Namibia) and even in bulk grain management systems that are not subsequently used. Little thought has gone into contingency planning for bumper harvests in SSA. Bumper harvests are rare and unpredictable, discouraging investment in fixed capital assets such as dryers or stores over and above what is needed for a “normal” season. Furthermore, the environmental conditions for bumper harvests tend to fall within regions with common bioeconomic features, a particular problem in regions of Africa where free cross-border movement of grains is now common.

Source: Coulter and Magrath (1994).

attacks both by the normal pest complex and, in the case of maize grain, the LGB, a devastating pest introduced into Africa from Central America in the late 1970s and associated with a significant increase in storage losses. However, the impact of bumper harvests on losses has not been measured, and overall, the effect is likely to be small compared with the losses resulting from unfavorable climate at harvest. African farmers sometimes have sufficient storage capacity so that good harvests can be accommodated in fixed stores, and in exceptional years, they are content to store surplus grain in sacks in their houses. Increasingly, however, subsistence farmers prefer to use bag storage rather than traditional structures.

TRANSPORT

In SSA, there is relatively little access to intermediate means of transport such as bicycles, handcarts, animal-drawn carts, or motorcycles (World Bank 1996). For smallholders, the movement of grain from field to farm store is often still by head load or bicycle and, in some places, by animal-drawn carts (Figure 2.9). For movement from store to market, commercial farmers hire or use their own trucks, while smallholders may use bicycles, tractors, trailers, pickups, and taxis, depending on availability of transport and quantity of grain transported. These modes of transport lead to high PHL, as the grain is not properly protected from exposure to the elements, insects, birds, and theft. Where farmers work in groups, they may be able to hire trucks; or, if scale can be achieved by local assembly, traders can be encouraged to pick up from villages.

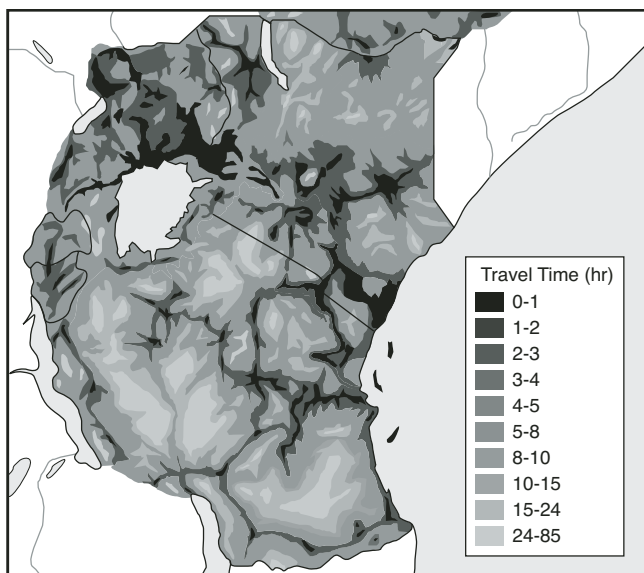
Africa has one of the lowest road densities in the world (WDR 2009), and transport costs can be five times

FIGURE 2.9. Taking the harvest home by oxcart



Source: Rick Hodges.

FIGURE 2.10. Travel time to market for farmers in Ethiopia, Kenya, Tanzania, and Uganda



Source: International Maize and Wheat Improvement Centre.

greater in Africa than in Asia. The poor condition of roads and the fact that the majority of villages do not have access to all-weather roads may cause extended delays (Figure 2.10) or even prevent transport to market. Poor road conditions contribute to physical PHL, as they increase the shocks to which grain kernels are subjected during transport. In a study undertaken in Uganda, Tanzania, and Kenya in 2008, it was found that transport costs make up about 76 percent of total maize marketing costs. The relative share of these costs varies from 64 percent of total costs in Kenya to 84 percent in Uganda and Tanzania. The second largest cost is hired labor for loading and unloading trucks. It amounts to 11.7 percent of total marketing costs, ranging per ton from US\$3.4 in Uganda to US\$13.3 in Kenya. The study highlights that these costs are quite high because a maize bag often goes through a number of markets before reaching the final consumer in large cities and thus requires loading and unloading at each intermediate stop.

LARGER-SCALE STORAGE

Storage of grain in market places is usually problematic, and generally not many purpose-built grain storage facilities are available. Small and medium traders rely on very cramped facilities in small rooms and lockups. Larger traders and millers often have purpose-built grain stores, and in some countries, the storage facilities of the earlier grain marketing

boards are available for hire. Some countries still retain their grain marketing boards (e.g., Malawi) or statutory bodies (e.g., Namibia and Botswana). Examples of the current status of larger grain stores are detailed in Box 2.5. In large-scale storage facilities, insect infestation is typically destroyed using fumigation with phosphine gas, combined with the spray treatment of bag stacks and store surfaces with synthetic insecticide as a hygiene measure. Standards of fumigation treatment are generally poor, and failure to kill all insects is common. This encourages the development of resistance to the fumigant,

BOX 2.5. Examples of large-scale storage facilities in African countries*

- **In Zambia**, there are large-scale improved storage facilities, mainly located near urban centers, and there is a private drying capacity of about 25,000 tons annually. The serviceable storage capacity of the Food Reserve Agency stands at 1.3 million tons, of which 76 percent is in the form of sheds, 1 percent as silos, and 13 percent as hard standing for cover and plinth storage.
- **In Ghana**, silo storage facilities were formerly operated by the government, which also ran mechanical drying and silo/warehouse storage facilities through the Ghana Food Distribution Company (GFDC) with a total storage capacity of about 47,500 tons, of which 19,000 tons are silos. GFDC formerly dried and stored grains but ceased operating in the early 1990s due to a lack of funding. There is some private sector involvement in grain storage facilities in major surplus areas; in this regard, private drying and storage facilities are available in the maize triangle between Techiman, Nkoranza, and Ejura.
- **In Malawi**, the National Food Reserve Agency (NFRA) manages the national strategic grain reserve, which handles maize and retains stock levels (currently 120,000 tons) as dictated by government. NFRA experiences very little loss (estimated 0.5 percent from cleaning of maize) due to its procurement procedure. From 2003, quality specifications were enforced for incoming maize. All incoming grain is fumigated and refumigated after 3–4 months in stock. NFRA has drying facilities but prefers that farmers do the drying so as not to incur extra costs. It buys from traders and farmers groups but not from individuals. NFRA offers a

Continued

BOX 2.5. Examples of large-scale storage facilities in African countries* (Continued)

number of services to farmers and the private sector including subsidized fumigation services, rental of warehouses, and hire of the weighbridge.

- **In Mali**, l'Office des Produits Alimentaire du Mali (OPAM) has a warehouse capacity of 130,000 tons, of which 35,000 tons are used for strategic reserves; the rest is rented out to the private sector. Due to poor threshing and winnowing practices used by farmers, there are high levels of physical contaminants in grains received. To clean grains before storage, OPAM has had to install a winnower for its warehouse in Ségou.
- **In Mozambique**, most storage structures were damaged during the civil war. However, under the present agricultural commercial strategy, the construction of silos and warehouses has been a priority, and some silos of 2,000-ton capacity have been built next to production areas. Likewise, silos of 15,000 tons have been constructed close to the main urban areas. Large silos are being leased to the private sector and managed by private entrepreneurs through arrangements with Millennium Cities Initiative. Some warehouses are registered with municipal councils, and warehouse space is rented to a variety of users, including both wholesalers and retailers who have nowhere else to store their goods.
- **In Rwanda**, storage infrastructures in rural areas are inadequate to meet the local production. The quality and maintenance of existing storage facilities are often ill designed and poorly maintained; there are 10,200 tons of farm warehousing. In addition, hermetic grain storage envelopes (mostly 50-ton capacity) have been supplied for a total capacity of 14,280 tons.

*Extracted from FAO/AfDB country reviews (FAO 2009b).

and although the incidence of resistance has not been investigated in SSA, it is known from Morocco (Benhalima 2004).

GRAIN MARKETING

In SSA, grain marketing is largely informal, with smallholders selling or bartering surplus food grain to households within their own locality or trading it on local markets.

Smallholders are grain sellers at harvest time but may become grain purchasers before the new harvest when grain is scarce.

BOX 2.6. Role of metrology

There is little or no legal metrology applied to small-scale grain transactions in Africa. Most trade is done by selling traditional units (often reused metal cans). The absence of reliable, calibrated weights and measures in rural areas places grain sellers at a substantial disadvantage; however, to date, the impact of this is unmeasured (Bennett 2010).

At this level, small-scale gifting and sales of grain also play an important social function, raising social capital and cementing social bonds. In many places, as more formalized markets have developed, grain is purchased metrically (e.g., there is a price per kg or for 100 kg of grain), and these quantities are then measured using scales. Due to both a lack of understanding and some unscrupulous buyers (who may tweak the scales), some farmers feel that they are losing out and actively avoid taking their grain to those markets that purchase using scales, selling it only locally using the traditional volumetric measures (Box 2.6). On leaving the farm, grain is bulked as it passes along a marketing chain of small traders through to large traders and millers. Only in South Africa (and, to a much lesser extent, Namibia and previously Zimbabwe), where agriculture is dominated by large-scale farming, well-developed commodity exchanges that enforce grades and standards, and futures markets, is formal grain trading a significant element of the economy.

The effect of moving from single-channel to liberalized grain markets has changed the nature and challenge of PHL, expanding the focus of attention for PHL reduction from the farm level to the value chain as a whole.

Effectively, as result of liberalization policies, grain markets have moved from supply chains, in which grains of fixed quality and price were produced to supply local markets, to more complex value chains with multiple-chain actors, variable prices, and differentiated product forms. This has also exposed farmers to competition, opening opportunities to address physical and opportunity PHL in ways that can greatly benefit not only small-scale producers but also other chain actors. PHL reduction can be achieved through upgrading to higher-quality value chains, increasing the volume of grain that enters the market through lower on-farm losses, and capturing price rises through arbitrage and innovative forms of collective marketing.

The impact on smallholders of the change from government-controlled supply chains to market-driven value chains in post market liberalization SSA is summarized

BOX 2.7. The impact of market liberalization on commercial grain storage and marketing

Prior to grain market liberalization in the 1980s–1990s, the old marketing boards, operating with varying degrees of efficiency, often retained relatively well-trained staff and limited losses by investing in good storage facilities and in equipment to clean and dry grain. The private traders that have replaced them often make do with what facilities they can find, and their staff has received little or no training, with only a few exceptions such as the pan-African trading houses (e.g., OLAM and Export Marketing). It is not clear to what extent this change has affected grain quality and PHL, but empirical evidence suggests that the effects are negative. The marketing boards took responsibility for training their staff, setting quality standards, buying produce, and ensuring that it met quality standards prior to storage. Private traders usually do not do these things, and an important challenge is the development of market institutions that can deliver services equivalent to those of the marketing boards.

Larger traders supply grain to institutions nationally and regionally. Commodity exchanges that assist with grain trading are still relatively uncommon, although increasing. It is rare that a premium is paid for better quality grain—purchases are based on a minimum acceptable quality. Most trading is undertaken without recourse to any specific grades or standards, the exception being when grain crosses national borders and regional standards may be applied (e.g., East African Community grain standards), but the enforcement of these standards is sporadic. The development of grades and standards that are commercially meaningful and enforced is an important element in the creation of a reliable and effective market. This also promotes a price premium for better-quality grain.

Source: Authors.

in Table 2.4. Liberalized grain markets have several key implications for PHL (Table 2.4):

- a. Farmers need to be better organized, act collectively, and acquire stronger group business and marketing skills in order to capture the opportunities offered by liberalized grain markets.
- b. The withdrawal of the state from grain storage and marketing, depending on the management of the state managed grain boards, may have left a vacuum in grain handling and storage know-how at the commercial level. The skills of private sector traders and trade associations need to be substantially strengthened, particularly because greater inter-temporal price variation increases the risks associated with holding stocks. This risk, which was occasionally subsumed by government-controlled marketing boards, yet not necessarily successfully, has now been transferred to farmers.
- c. Quality norms are now set within the value chain rather than by marketing boards. This increases the potential premium for quality but is also a basis for discounting the price of poor-quality grain at the farm gate.
- d. Greater price variability makes the cost of purchasing grain uncertain. For deficit producers, reducing PHL makes more of their own production available for consumption and reduces the quantity of grain that needs to be purchased to meet household needs.

Collective marketing

Collective marketing by smallholder farmers has traditionally been supported by the creation of community stores in many African countries, typically small bag stores holding up to about 50 tons. In theory, these should work well, as they are easily manageable with a small amount of training; however, several factors threaten their

TABLE 2.4. Possible impacts on smallholders of PHL under liberalized markets

SITUATION BEFORE MARKET LIBERALIZATION	NOW	IMPLICATIONS
Grain boards occasionally provided markets for surpluses for some farmers, usually the larger ones	No assured markets	Farmers need better organization, collective action, and stronger business and marketing skills
Farm gate prices often unrelated to border parity price	Farm gate price related to border parity price	Price variation risk passed to farmers
Grain, under mandate of boards, enters the supply chain at minimum acceptable quality	Quality standard can vary in-chain	Better postharvest management practices rewarded
Pan-territorial and seasonal pricing, so farmers often sell knowing the cost of buying back for food security	No fixed prices, so cost to deficit producers of buying grain uncertain	Lower physical losses on farm, increased food availability, and reduced need to buy household deficit
State-controlled marketing boards often provide services, handling and storing grain	Emerging private sector taking over the role left by the marketing boards	Lack of skills in grain management may lead to higher losses and lower quality; many postharvest operations previously conducted by marketing boards pushed down to farm level

Source: Authors.

success. They rely heavily on successful group formation, good access to transport, a favorable market, and long-term consistency of farmers in generating sufficient surplus crop of a marketable quality. Small and marginal farmers commonly live far from the sale or export point for their produce. Transport costs can be a significant proportion of the direct costs of production and are often underestimated. It is common for individual farmers to go with their product to market to ensure safety, but the disadvantage of this is that they may spend some of the sale price on an overnight stay or other expenditure, and this can add substantially to cost. Significant opportunities for transport cost saving exist, but for various reasons (e.g., not all producing at the same time, not being part of the same social group, not trusting others), farmers usually prefer to transport individually.

Collective marketing can take various forms, including bulking up for marketing by farmers groups, producer organizations, or cereal banks.

Cereal banks are community-based institutions that acquire, value, and supply grain with the intention of improving food security during the hungry season or extended droughts. Grain is bought from the village or elsewhere when prices are low, just after harvest; it is stored until it is needed and then sold to the villagers at a reasonable price. The villagers are paid a better price for their grain when the market prices are low, and they then have cash to meet their expenses. When the market prices are high and their granaries are empty, they can buy grain from the cereal banks at below-market rates. Furthermore, since the bank is in the village, farmers do not have to travel long distances to buy grain and then transport it back home, which saves time and money. However, cereal banks have had a poor success rate; have had difficulty competing in spatial arbitrage; and have suffered from accumulated consumer debt, slow collective decision making, corruption, and loss of original capital. Where depletion of capital was being avoided, an unsustainable level of external supervision was required (Coulter 2007). All the collective marketing initiatives have a higher probability of success when they complement agricultural intensification and involve bulking substantial quantities of produce for quality-conscious commercial buyers.

A detailed account of cereal banks is presented in Annex 5.

While the concept of community cereal banks in terms of improving food security of vulnerable communities is clearly appealing to many agencies, sustainability is a huge problem (CRS 1998). Documentation on cereal banks is limited, making it difficult to get accurate figures of the investment in cereal banks, but it has certainly been significant in the Sahel region. Typically, cereal banks depend on

external support; and if that support does not identify and take into consideration enabling factors nor does not provide sustainable solutions and ceases, most cereal banks seem to become bankrupt. The reasons for the weaknesses of most cereal banks were summarized as follows:

- Insufficient understanding that net margins are thin—there's little room for error in trading.
- Cereal banks frequently make management errors—inexperience, slow collective decision making, and social pressures lead to poor decisions in terms of timing and pricing of purchases and sales.
- The managers of cereal banks are managing collective goods and not their own private affairs—hence, there is little incentive for cost minimization or efficient management.
- Speculative storage is less profitable and more risky than most people assume.
- Grain that is loaned out by cereal banks is frequently not paid back.
- Cereal banks often suffer from corruption and other abuses of the cash box.
- Support agents can become predators, stealing the money of the cereal banks that they are supposed to be helping (CRS 1998).

That said, conditions for localized successes and failure of cereal banks need to be better understood. A recent appraisal of an IFAD project in Chad found that 64 percent of cereal banks established between 2005 and 2007 remained viable as compared to 80 percent in a similar project in Niger. In both cases, the factors critical for sustainability appeared to be year-to-year variability in harvests which required food security “smoothing”; limited market integration making it advantageous to save grain rather than monetize it; membership of the more vulnerable who are most in need of access to grain banks; and the strong role of women in management, reinforced by the provision of management and technical support. In emergency relief situations, cereal banks can play a temporary role supplying food on favorable terms, yet require significant resource investment. However, social protection programs such as cash or food for work and conditional (or unconditional) targeted cash transfers can be more effective, depending on the development objective.

ESTIMATING THE MAGNITUDE OF PHL IN SSA

In the 1970s, the popular view was that PHL were high at the farm level and that traditional practices were the problem.

TABLE 2.5. Generalized loss profiles for major grains in Eastern and Southern Africa

CLIMATE TYPE CROP SCALE OF FARMING	HOT/HUMID MAIZE SMALL	WARM TEMPERATE MAIZE LARGE	ARID/DESERT SORGHUM SMALL	ARID/DESERT MILLET SMALL	HOT/HUMID RICE SMALL
Harvesting/field drying	6.4	2	4.9	3.5	4.3
Drying	4	3.5	—	—	—
Shelling/threshing	1.2	2.3	4	2.5	2.6
Winnowing	—	—	—	—	2.5
Transport to store	2.3	1.9	2.1	2.5	1.3
Storage	5.3	2.1	2.2	1.1	1.2
Transport to market	1	1	1	1	1
Market storage	4	4	4	4	4
Cumulative % weight loss*	17.9	11.3	12.6	9.3	11.4
Cumulative % weight loss**	16.5	11.2	12.0	9.3	11.9

Note: The estimates are weighted average according to reported figures.

*Cumulative weight loss assuming all grain retained on farm, none marketed.

**Cumulative weight loss assuming that in the first three months, 50 percent of grain stock marketed does not incur farm storage losses.

Source: APHLIS.

However, some authors have argued that traditional practices are an unlikely culprit, as farmers have survived difficult conditions over long periods by adapting their practice to prevailing circumstances (Greeley 1982); others argue that they have come to accept high PHL as part of a more complex overall livelihoods strategy that trades off these losses against the cost of reducing them. Nevertheless, serious losses at the farm level do sometimes occur as a result of multiple factors such as agricultural developments for which the farmer is not pre-adapted. These include the introduction of high-yielding varieties that are more susceptible to pest damage, additional cropping seasons that result in the need for harvesting and drying when weather is damp or cloudy, increased climate variability, or farmers producing significant surplus grain that must be stored on the farm in larger quantities and for longer periods.

Loss figures for grains have been expressed in different ways, and rarely do these include all steps in the postharvest chain. In the 1970s–1980s, the initial international efforts to quantify PHL for grains mostly focused on grain once it had entered farm storage. Few data were gathered on harvesting, drying, or transport losses. Although these data gaps remain, there have been recent efforts to estimate the cumulative losses of grains along the chain, although most efforts remain scattered.

The magnitude and location of PHL are poorly known because they are still frequently “guesstimates,” are relatively difficult to trace, and the sources themselves may not be very reliable. Demand for better PHL estimates of cereal grains has resulted in the development of the APHLIS

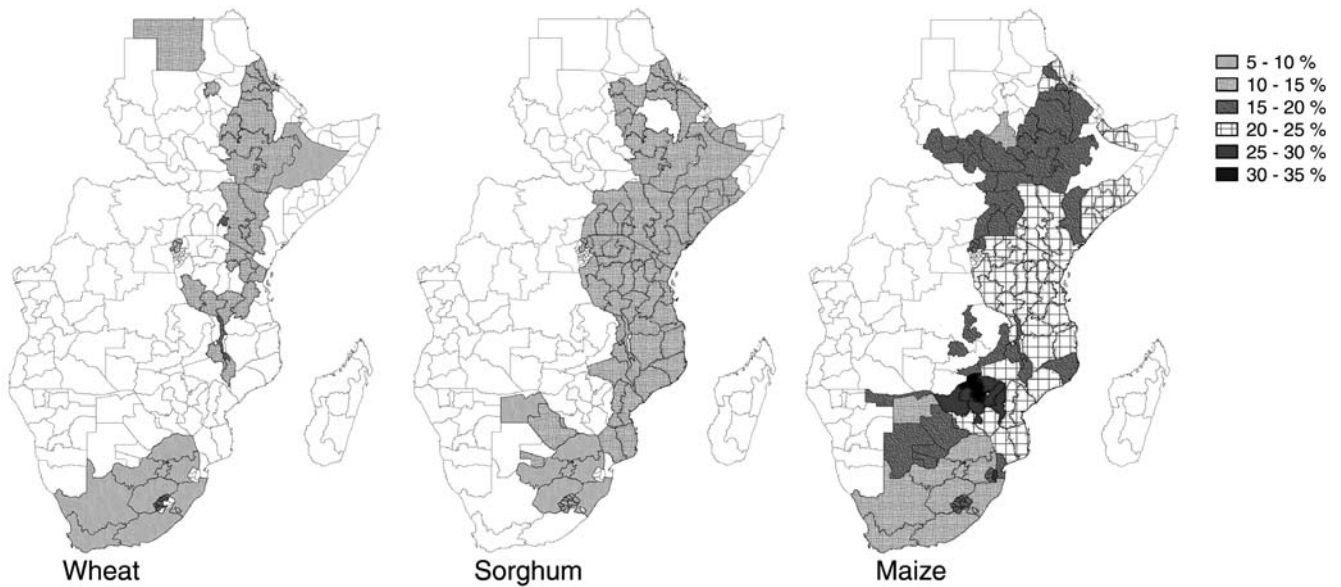
(<http://www.aphlis.net>).² The database presents estimates of PHL by commodity along different chain steps, including harvesting, drying, storage, and transport, but not processing activities such as milling. This effort has been supported by a network of local experts who contribute the data on which the model operates and validate its outputs. The estimation model proposed by APHLIS is simple, robust, and transparent—but it is no magic wand for situations where only little or low quality data is available.³

The magnitude of cumulative weight losses tends to vary according to climate, crop type, and scale of farming. Table 2.5 presents PHL estimates as weighted averages, which vary from year to year depending on factors like unseasonal rains,

2 APHLIS was funded through the European Commission’s Joint Research Centre (JRC) with the technical support of the Natural Resources Institute (NRI, UK) and Federal Office for Agriculture and Food (BLE, Germany), in association with the UN FAO, the Association for Strengthening Agricultural Research in East and Central Africa (ASARECA), and the Southern Africa Development Community (SADC). APHLIS estimates PHL by cereal crop, by country, and by province in East and Southern Africa (but not yet West/Central Africa). The system went online in March 2009. It combines a PHL calculator, a database of key information, and a network of local experts who contribute the latest data and verify loss estimates. There is decentralized ownership of data by country.

3 The reliability of the calculations made through APHLIS depends on the quality of PHL assessments available. For some crops or process steps, assessments were conducted many years ago. Similarly, under the lack of a standardized methodology for PHL estimations, many of the surveys available applied methodologies that make the calculations derived from them not very reliable.

FIGURE 2.11. Estimated percentage of cumulative postharvest weight loss from production of various grains in East and Southern Africa for 2007



Source: APLHIS.

pest attacks, etc. Appropriate technical and managerial solutions to these losses will need to reflect such variations. Using APLHIS data, weighted average losses for East and Southern Africa, according to reported figures, are estimated to range from 10–20 percent, with estimates varying between regions within countries (Figure 2.11). There have often been demands for simplified loss figures; this has led to the PHL of maize for a country or region being reduced to a single figure representative of many years. However, such an approach is likely to be misleading because PHL may be due to a variety of factors, the importance of which varies from commodity to commodity, from season to season, and according to the enormous variety of circumstances under which commodities are grown, harvested, stored, processed, and marketed. It is therefore important to not only work with figures that are good estimates at the time and in the situation in which they are taken but to also be aware that in other situations, the figures will differ. This necessitates regular recalculation of loss estimates with the best figures available.

Recent efforts to estimate accumulative weight losses in Ghana show similar figures as in the case of cereals in Eastern and Western Africa (Table 2.6). The losses vary by grain crop and season, with the largest estimates found for maize in the main season and the smallest for sorghum in minor season.

The above estimates of grain losses appear to be well below the 40–50 percent loss estimate frequently cited by

development practitioners, yet they are still too high to ignore.⁴ In Eastern and Southern Africa, which account for about 40 percent of SSA's estimated grain supplies, PHL are estimated at US\$1.6 billion a year (Table 2.7). This is assuming weighted average losses of 13.5 percent (taking APLHIS data as reference) of an estimated value of production of approximately US\$11 billion (based on the FAO statistics). Extrapolating these figures to Central and Western Africa to estimate *the value of total PHL in SSA, the figure could reach nearly US\$4 billion a year*, out of an estimated annual value of grain production of US\$27 billion in 2005–07.

IMPACTS OF PHL

Postharvest technologies can contribute to food security in multiple ways. They can reduce PHL, thereby increasing the amount of food available for consumption by farmers and poor rural and urban consumers. For example, the control of the LGB greatly reduced the loss of maize in on-farm storage among smallholders in a number of African countries, improving their food security (Golleti 2003). The benefits to consumers from reducing losses include lower prices and improved food security. In addition, postharvest activities such as processing and marketing can create employment (and thus income) and better food security in the agricultural

⁴ It is the losses of perishable fruits and vegetables, cassava, and also meat and fish that can be in that high range, but not grains.

TABLE 2.6. Mean estimates of PHL for grains in Ghana, % of total production

	MAJOR SEASON				MINOR SEASON			
	MAIZE	RICE	MILLET	SORGHUM	MAIZE	RICE	MILLET	SORGHUM
Harvesting	5.59	1.21	1.88	1.09	2.10	0.00	0.00	0.00
Assembling at farm	0.86	0.50	1.55	0.54	0.00	0.00	0.00	0.00
Temporal processing	2.97	0.60	1.16	1.97	0.40	1.16	0.50	0.00
Grading and sorting	0.45	0.00	0.00	0.60	0.00	0.00	0.00	0.00
Packaging and bagging	1.10	0.23	0.13	0.02	1.21	0.00	0.50	0.63
Transport to home	2.66	0.49	0.07	0.15	0.65	0.55	0.58	0.00
Storage at home/farm	1.25	1.17	1.24	1.73	2.73	7.30	3.14	1.27
Loading to vehicle	1.69	0.11	0.03	0.51	0.16	0.00	0.04	0.10
Transport to market	0.05	0.24	0.22	0.04	0.77	0.00	0.07	0.20
Unloading from vehicle	0.87	0.20	0.03	0.00	0.22	0.00	0.00	0.00
Market storage	0.76	0.79	0.33	0.83	1.40	0.00	0.00	0.00
TOTAL	18.25	5.54	6.64	7.48	9.64	9.01	4.83	2.20

Source: University of Ghana (2008).

sector. Therefore, reducing PHL clearly complements other efforts to enhance food security through improved farm-level productivity

While the gains from reducing postharvest losses can be significant, there are also costs associated with those efforts, which need to be considered when formulating PHL reduction strategies. Nevertheless, there are significant

opportunities for promoting food security through PHL reduction, especially in the current era of high food prices. Thus, efforts to increase production need to be balanced with corresponding efforts to achieve gains in reducing PHL. With only 1 percent reduction in PHL, annual benefits of US\$40 million may be possible, benefiting not only producers but also other actors along the chain, including SSA consumers. Viewed in a different perspective, an annual value

TABLE 2.7. Estimated value of weight losses for Eastern and Southern Africa based on annual production and estimated % PHL, 2005–07 average

	PRODUCTION FOR 16 COUNTRIES OF EASTERN AND SOUTHERN AFRICA (MILLION TONS)	AVERAGE LOCAL PRICES (US\$/TON)**	ESTIMATED VALUE OF PRODUCTION (US\$ MILLION)	REGIONALLY ESTIMATED AVERAGE % WEIGHT LOSS	VALUE OF WEIGHT LOSSES (US\$ MILLION)
Maize	27.01	194.71	5,528	17.5	920
Sorghum	4.72	250.02	1,181	11.8	139
Millet	1.67	305.34	510	11.7	60
Rice (paddy)	5.15	405.53	2,089	11.5	240
Wheat	5.25	274.36	1,441	13.0	187
Barley	1.71	281.53	481	9.9	48
Total	46.18		10,960		1,594

Note: *Countries included are Botswana, Eritrea, Ethiopia, Kenya, Lesotho, Madagascar, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Tanzania, Uganda, Zambia, and Zimbabwe.

**Average producer prices from FAOSTAT.

Source: Calculations based on FAOSTAT and APHLIS data.

loss estimate of US\$4billion (i) exceeds the total value of cereal food aid SSA received over the last decade;⁵ (ii) equates to the annual value of cereal imports of SSA, which range annually between US\$3–7 billion over the 2000–07 period; and (iii) is equivalent to the annual caloric requirement of at least 48 million people (at 2,500 kcal per person per day).

However, the loss of actual grain is not the only concern; the economic losses that arise from the failure to market grain or to sell in a higher-value market may be even more significant. These result from the poor functioning of value chains due to inadequate transport linkages, lack of market infrastructure and information, lack of credit, and failure to deliver at the required quality. Quality issues are a major barrier to market access, both regionally and internationally. In cereal grains, aflatoxin contamination is an increasingly important food safety issue—especially on maize—which poses a serious health hazard to consumers (see Annex 2, Project 24).

5 Estimated FOB value of food aid shipments of cereals over the period 1998–08, assuming the following composition of shipments: wheat (70 percent), maize (20 percent), and rice (10 percent).

The above economic estimations have been restricted to weight losses; however, the size of the economic value of total losses could be substantially higher if the losses associated with missed market opportunities were considered. Although opportunity losses are more difficult to estimate than weight losses, there is a need to better understand their importance. The establishment of postharvest weight loss baseline data, as well as a better understanding of the magnitude of the opportunities lost, are both critical to better inform development experts, policy makers, and industry stakeholders of the options offered by the systematic adopting of PHL-reduction strategies. The exercise presented here on PHL estimations also suggests the need for an approach that balances the costs and benefits of producing more food to cover the losses caused by the lack of appropriate PHL-reduction technologies and practices.

While in this chapter the focus has been on the nature and magnitude of the losses that can occur in cereal chains in SSA, the next chapter will focus on the technological options that have been implemented and are available to minimize PHL in grains.

3. TECHNOLOGIES AND PRACTICES TO REDUCE PHL: A REVIEW

The range of strategic options to promote postharvest system improvements incorporate a range of technologies and practices that, if adopted by different actors along the chain, can contribute significantly to reducing PHL. The range of technologies and practices to promote postharvest improvements can be grouped into three main categories: (i) postharvest grain management along the chain, (ii) pest/fungi management and storage structures, and (iii) institutional arrangements for grain marketing. A fourth category related to communication and learning complements the efforts to support technological improvements and adoption of improved practices. There is a broader set of factors related to the estimation of proper PHL baselines which include the establishment and implementation of quality and safety standards; improved transportation infrastructure; enabling policies, etc., These need to be reviewed and understood to best ensure the adoption of identified cost/effective technologies and practices. This chapter will focus on presenting an overview of some of the most widespread PHL reduction technologies and practices (presented in Figure 3.1) and of the efforts undertaken by development partners to support their adoption, which are summarized in Annex 2. Chapter 4 will focus on an analysis of the supporting services and broader factors facilitating the achievement of PHL objectives.

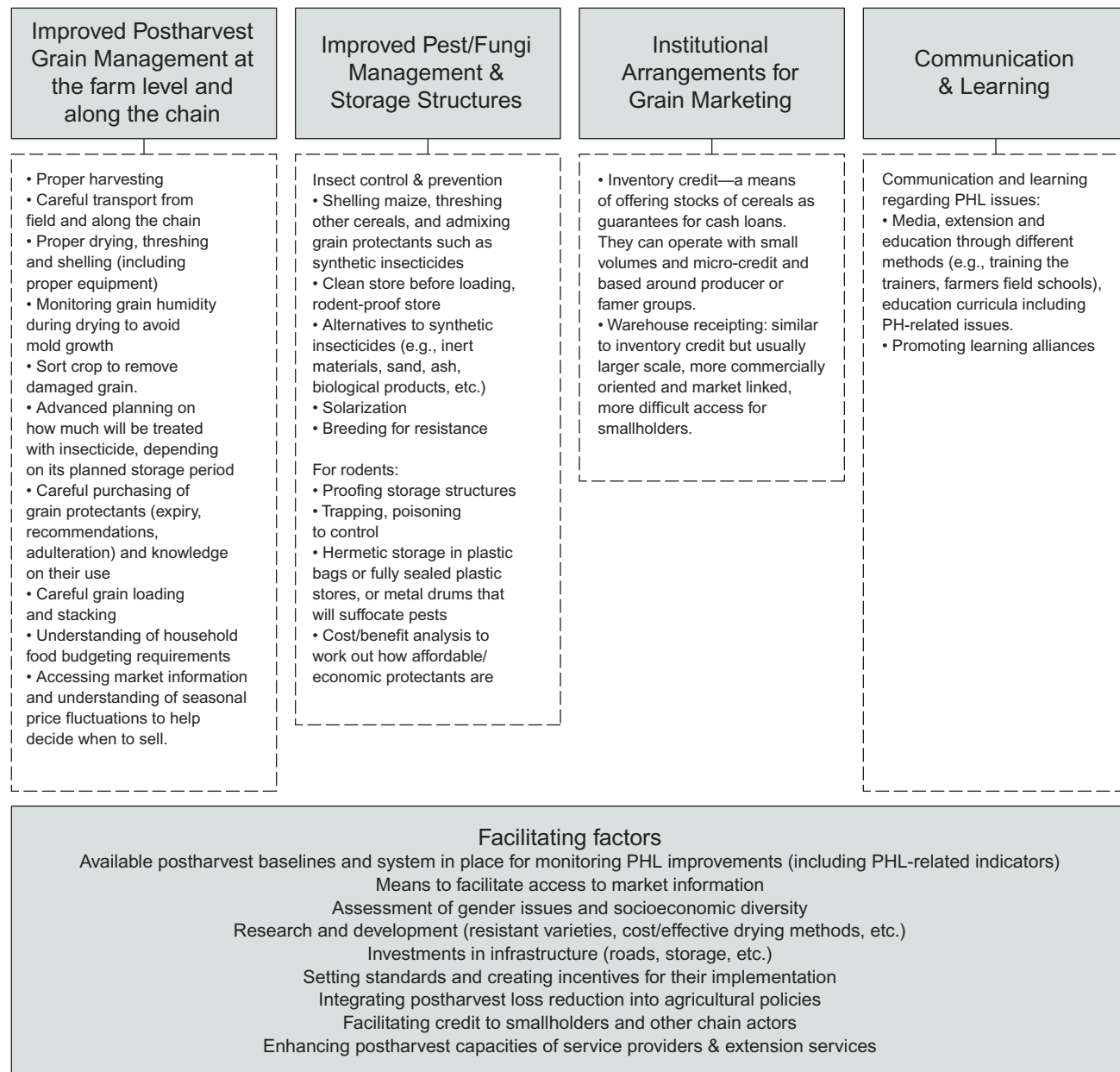
POSTHARVEST GRAIN HANDLING AND MANAGEMENT ALONG THE CHAIN

A range of good practices to be applied along the postharvest chain to reduce PHL have been identified and sometimes summarized in codes of recommended practices. PHL can be mitigated by appropriate handling and managing of the product along the chain to minimize the effect of biological and environmental factors on product deterioration and avoid product contamination. For example, in the case of mycotoxins, the Codex Alimentarius Commission has elaborated the Code of Practice for the Prevention and Reduction of Mycotoxin Contamination in Cereals. The Code presents good agricultural practices (GAP) that represent the primary line of defense against contamination of cereals

with mycotoxins, followed by the implementation of good manufacturing practices (GMP) during postharvest stages to satisfy cereal demands for human food and animal feed. A discussion of some of the most significant good practices that can be implemented by farmers to reduce PHL, including the selection of the right variety, proper harvesting, drying, milling, shelling, and so on is presented below. This is followed by the analysis of the set of proper practices and technological options for grain management during storage. The institutional arrangements for grain marketing are discussed at the end of the section.

The choice of grain variety is a critical initial step in preventing losses during postharvest stages. In some locations, especially parts of eastern and southern Africa, high-yielding varieties (HYVs) of maize are grown by farmers as cash crops. HYVs have the disadvantage that they require the purchase of agricultural inputs and their availability relies on commercial seed supply. They are also more susceptible to pest attack in storage and, consequently, are sold soon after harvest. There have been efforts to breed maize varieties with increased resistance to storage pests over many years (Kumar 2002), but to date these have not resulted in crops with both desired agronomic characteristics and the required resistance. More progress is being made with pulses where in Malawi the Programme for Africa's Seed system has discovered a common bean landrace (KK35) that is not damaged by either *Zabrotes subfasciatus* or *Acanthoscelides obtectus*. Future progress with grains cannot be ruled out. Most recently, efforts to produce aflatoxin-resistant maize varieties are delivering very promising results.

Harvesting efficiently and at the right time is critical to avoid losses down the chain. PHL occurs when the harvest is too early, as the crop will still be moist and grains not filled, or too late, as attacks by insects, birds, and rodents will have begun. When harvesting is done close to the start of a rainy season, a delay can result in the harvest being undertaken in damp, cloudy weather, and the crop will be insufficiently dried. For most smallholders in Africa, mechanical harvesting is not an option because the scale is inappropriate and the

FIGURE 3.1. Examples of strategies to reduce PHL and promote overall postharvest system improvements

Source: Luz Diaz Rios.

cost unaffordable. The only exception may be in rice cultivation where mini-combine harvesters have been tested by IRRI/WARDA (Annex 2, Project 19). The HIV/AIDS pandemic has reduced the ability of many communities to manage peaks in labor demand, such as harvesting, but few projects have responded to this issue specifically—an exception is Project 9, Annex 2. In this example, an IRRI-type two-wheeled tractor that can be used for soil tillage, maize shelling, wheat harvesting, and threshing is being manufactured in Uganda (Figure 3.2).

Better approaches to grain drying are needed. In hot, dry climates, sun drying is easily achieved; the approaches taken may not need any specific improvements except that of preventing exposure of the product during drying to dust particles and other foreign material, insects, and birds. However, in more humid places or where harvest time may be cloudy, other approaches could be used that would lead to a reduction in PHL and, especially in the case of maize, can limit possible contamination with mycotoxin. Determining the moisture content in several spots of each load of the

FIGURE 3.2. IRRI-Type two-wheeled tractor provides transport, can be used for tillage, harvesting, shelling, or threshing



Source: Rick Hodges.

harvested grain and, most importantly, at the end of the drying process is a critical control point to reduce postharvest deterioration.

Postharvest improvements can often be made through training and development of appropriate skills in postharvest handling and managing. However, in humid producing regions, proper drying becomes a critical constraint to postharvest improvements. In humid regions, drying cannot be managed with proper handling or management practices alone, but in combination with cost-effective drying systems and business models that create incentives to farmers for investments in proper drying technologies. The search for these cost-effective drying technologies and business models needs to be a critical element of current and future applied-research efforts. Some of the drying technologies developed for grains are discussed below.

The use of mechanical dryers for higher-value crops can give reasonable paybacks. IRRI in Southeast Asia, for example, installed 7,000 flatbed driers fuelled by rice husk for rice drying in Vietnam. However, IRRI's target for establishing drying facilities is not farmers but contractors who provide a drying service to farmers and the commercial sector (mainly rice millers and a few traders). Since 1991, there appear to have been no successful introduction of dryers to individual farmers in Southeast Asia except the SRR low-cost dryer in Vietnam (US\$100, 1-ton capacity), but this dryer served as an entry point to demonstrate the advantages of dryers and is now being replaced by larger flatbed dryers for contractors and millers (Gummert 2010).

For the humid tropics, a specific drying crib has been designed for holding maize cobs (Boshoff 1979). It is of

wooden construction with chicken wire mesh to encourage good ventilation and is an improvement over more traditional designs in that it is longer and thinner to aid better ventilation. These drying cribs have been used in many places and were a centerpiece of a project to improve maize quality in Ghana, where the extension package from Sasakawa Global 2000 included drying cribs for cobs and insecticide for admixture to grain. However, such cribs are expensive to build and may suffer from termite damage. In some locations where rain is possible at the time of harvest, tarpaulins have been supplied to cover grain during rainfall; this approach will become increasingly important as climate change makes erratic and unpredictable rains more likely.

A grain dryer incorporating a solar air-dryer and a photovoltaic power-assisted fan has been designed in Malawi to dry maize. The dryer can dry 90 kg of maize grain per batch and is considered cost effective, with a payback period of less than one year if surplus grain is dried and sold in the market. It is not clear whether there has been any uptake of this device.

The single most widespread postharvest technology adoption in the SSA grain sector during the past 30 years has been the emergence of the small-scale hammer mill. In some cases, this has gone from zero hammer mills (e.g., all maize pounded in the household by women) to blanket coverage (e.g., all communities with a hammer mill business) within just a few years (Mallet and Du Plessis 2000). This emergence of small hammer mills has largely followed the pattern of rural electrification. Most mills operate on an in-kind payment basis, with consumers bringing maize to the mill and receiving maize flour in return for payment in maize and by-product. The emergence of the small-scale maize milling sector in almost all countries has largely come without any government support or donor engagement. The adoptability of the hammer mill was likely supported by clear benefits for women, as it reduced drudgery and increased time available for other productive activities.

Another success story is the promotion of a new rice thresher in the Senegal River valley. This is an example of a technology successfully adopted in the context of growing labor constraints and higher rural wages. The problem of high losses of manual threshing had been identified there in the mid-1990s (FAO 1994). A collaborative program between WARDA and IRRI identified an improved rice thresher-cleaner and then engaged local manufacturers and end users to develop an African technical solution that is affordable, locally constructed, and acceptable to farmers in the rice-growing areas. The new rice thresher produces 6 tons of rice per day

with a grain-straw separation rate of 99 percent, compared with manual threshing, which yields only 1 ton of rice per day and requires additional labor for winnowing (Diagne et al. 2009). A high internal rate of return made the new thresher extremely attractive for use in the Senegal River valley, but the average purchase price of US\$5,000 makes it unaffordable for many smallholders.

When the thresher is used for 90 days, the benefit-cost ratio reaches 2.3, well above unity. The economic life of the new thresher is five years, with a salvage value of 30 percent of the purchase price (Diagne et al. 2009). The technology became so popular in the Senegal River valley, following its commercial release in 1997, that its impact was recognized in 2003 when the president of Senegal presented the ASSI team with the special prize for science research. Today, more than 50 percent of total paddy produced in Senegal is threshed with the ASSI thresher-cleaner, and there are the spill-over effects in other West African countries (Table 3.1). As a result of this experience, WARDA and other partners are using this approach for further development of rice harvesting technology. The ASSI thresher has also been successfully modified for threshing fonio, through a collaborative project that involved FAO, CIRAD, and national research institutions in Guinea, Mali, and Burkina Faso (Annex 2, Project 27).

STORAGE AND PEST MANAGEMENT

On-farm storage

Adoption of an appropriate and effective method of grain storage can significantly improve the quality and quantity of grain at outturn. For this reason, there has been a strong focus on the extension/modification of existing store types as well as on the introduction of new storage types.

One approach to reducing PHL during storage is either by modifying existing store types so that they perform better or by introducing existing traditional but more effective store types to those communities that *do not already use them* (for example, mud silos). Mud silos (Figure 3.3) have been promoted in some districts of northern Ghana, where their use is not traditional. They offer potential for the better storage of food grains than more open store types can offer, as they are well sealed. Survey work by Opportunity Industrialization Centre, Tamale, has demonstrated that PHL for grain stored in them remain low regardless of whether the crop was treated with a grain storage pesticide (Azu 2010).

In Gushiegu/Karaga district, over 1,000 silos have been constructed through promotion projects by the Ministry of Food and Agriculture, Ghana, Adventist Development and Relief Agency, and OICT, where skilled artisans from mud silos-building groups have constructed silos for those groups that do not already use this technology. A survey of the new silos was undertaken for information to add to the experiences of earlier silo-promotional campaigns carried out in the region (Annex 2, Project 13). Varying degrees of success were noted, and important lessons were learned that have application for the successful extension of any technology (Box 3.1). Farmers provided evidence that there is much less insect infestation when commodities are stored in sealed mud silos. Sixty survey respondents, owning both mud silos and other stores, in Gushiegu/Karaga during the 2002 storage season reported that of a total of 565 kg of insect-damaged maize, only 6.5 percent of the damage occurred in mud silo structures. The remaining 93.5 percent of storage losses occurred in other local stores (e.g., kambons, jute sacks, and kunchuns). The survey concluded that mud silos offer the benefits of improved food security by reducing storage losses and

TABLE 3.1. Spillover effects from the ASSI thresher cleaner

COUNTRY	NUMBER OF TECHNOLOGIES	USE RATE (%)	PROJECT PARTNERS
Senegal	250	75	WARDA, ISRA, SAED, SISMAR, AGRITECH, Local artisans, Producer groups
Mauritania	50	15	SONADER, CNRADA, EL MALLY, GIE
Mali	100	10	IER, Office du Niger, local artisans
Burkina Faso	10	10	INERA, CGF, PAFR, producer groups, local artisans
Ghana	11	—	MADR, World Bank, KAPONG Project
Côte d'Ivoire	7	—	ANADER, Local artisans

Source: Diagne et al. (2009); information from WARDA.

FIGURE 3.3. Sealed stores—mud silo (a) and metal silo (b)**a. Mud Silo**

Source: Rick Hodges.

**b. Metal Silo (Postcosecha Type)**

that they enable crops to be stored for longer, thus giving greater marketing flexibility.

Modified farm stores can provide solutions to long-standing storage problems in Africa and elsewhere. While grain storage structures help protect against crop losses from insects, rodents, molds, theft, and fire, traditional designs are not always effective, and building them is difficult for poor communities where the hardwood supply is limited due to deforestation. Smallholders in Zimbabwe experimented with PVC pipes filled with concrete to replace timber, with the added advantage that rodents and termites don't attack these posts. They also produced a manual and video for facilitating extension to other countries (Annex 2, Project 10); however, the initial expense of the pipes and concrete has prevented farmers from widely adopting these modifications.

In Zimbabwe, storage structures were promoted that were made of a concrete base with burnt brick walls and a thatched roof. This was basically a modified version of the traditional pole and mud structure with a timber base resting on stones. The modifications were mainly in response to farmers' concerns over dwindling construction resources and official concerns regarding the threat of the arrival of LGB in Zimbabwe. The promotion centered on the construction of a model granary, with the participation of local builders and agricultural extension staff, and grain treatment demonstrations at the model site when the granaries were loaded with the farmer's own maize. Farmers with excess maize were prepared to sell part of their harvest to construct their own granaries using the trained builders. The model storage facility had a capacity of about 3 tons, and the total cost of the store was equivalent to 1 ton of maize at the time. The

model granary sites became the focus of further postharvest demonstrations and training.

Introduction of new store types have been done, most of them recently. Sealed stores offer good opportunities to minimize PHL. These stores, with a reasonable degree of sealing but not fully airtight (hermetic), offer an effective barrier to pest attacks but may require action to kill any pests at the time of loading (e.g., fumigation). Those that can be made hermetic have an additional advantage in that the gas composition in the store changes over time, oxygen is depleted, and carbon dioxide rises so that any pests present are killed. A wide range of different structures can be sealed, and these can take the form of metal or plastic drums or of plastic bags, some of which may be fully hermetic.

Clean metal oil drums (200 liter) have been stores of choice (promoted by the Collaborative Research Support Program project in Senegal and other countries) for cowpea storage but would be equally good for grain storage. The drum is filled with about 150 kg of sundried cowpeas and fitted with its cap. This should be greased before tightening to ensure that it is airtight. Similar-sized plastic drums with tight-fitting lids would be equally effective.

During the 1970s, tanks of about 1-ton capacity made of corrugated, galvanized iron became popular in Swaziland; and by the late 1990s, about 30,000 tanks were in use. The design was adapted from water tanks, and, although there was no subsidy or major extension program, farmers were encouraged to place them on stands in the shade and to fumigate the grain with phosphine. This type of storage continues to offer an excellent option to reduce PHL.

BOX 3.1. Mud silo promotion in Northern Ghana (Annex 2, Project 13)

Following the construction of over 1,000 mud silos in northern Ghana, with variable success, a review concluded the following:

1. Community-based organizations such as farmer groups or marketing cooperatives were needed as information channels, for the selection of the appropriate communities within which to promote silos, and to implement capacity building training programs.
2. A more rigorous and inclusive approach should be used (i.e., not top down) to decide on the communities to be involved and the specifics of the promotion methodology.
3. Farmers must be sensitized to pros and cons of mud silos and informed of the materials that must be prepared in advance of construction.
4. It is essential to ensure that the selection process takes into account the actual needs and priorities of the potential farmers and households as well as the availability of resources key to the construction and maintenance of the silos. The participation of these potential household beneficiaries must be confirmed.
5. In view of the relatively large number of structures that have collapsed in the promotion areas, it should be a prerequisite that in subsequent promotions an adequate number of farmers be trained in the care, maintenance, and utilization of the structures.
6. The design of structures must take account people's diverse needs (e.g., size of opening be narrowed and design types be available for categories of people that include the weak, strong, adults, children, etc.), and compartments must be introduced for increased usefulness and strength of structures.
7. Beneficiaries need to be informed on how to locate and maintain structures for security and durability.
8. Both new and old users of silos need training in storage practices to prevent the introduction of pests during loading.

Source: DFID.

While postharvest specialists around the continent are familiar with the Swazi metal tank, it has hardly been disseminated in other African countries. Instead, metal silos (Figure 3.3(b)), of a design originally introduced into Central America by the Swiss Agency for Development and Cooperation's PostCosecha project, have been extended (Annex 2, Project 14). These are available in a range of capacities from 0.1 to 3 tons. They achieved very high adoption rates in Central America over a period of more than 20 years by a social marketing approach that attended to all elements of the marketing mix—product, price, distribution, and promotion (Coulter et al. 1995; Coulter and Schneider 2004). By 2008, the project had recorded the transfer of 586,000 metal silos, mainly to smallholder farmers who received a wider range of benefits than originally expected.

The main technical constraints for farmers using metal silos are the need to have their grain dry before storage and the need to undertake phosphine fumigation against pest infestation. In some African countries, there is an official prohibition on farmers using fumigants; in such situations, it would be possible to protect the grain by depleting oxygen

in the silos. This can be done by placing a burning candle on the grain surface and then sealing the silo. In an appraisal of the potential for promoting metal silos in Tanzania and Mozambique, it was concluded that it is critically important to be able to obtain galvanized iron sheets of suitable quality. In both countries, the available sheeting failed to meet standards established under the PostCosecha project. It was concluded, though, that the lack of supply did not pose a major problem. A postharvest project can create the necessary demand in its area of operation to attract commercial supply of galvanized iron sheets that would be cut by local profilers and, subsequently, retailed through local hardware stores. However, to avoid facing an endless chicken-and-egg supply problem, a project would need to make the first order itself, pricing the sheeting at a level that simulates expected commercial margins (Coulter and Schneider 2004).

In the 1997–2007 period, FAO was involved in extending metal silos in nine African countries (FAO 2008). Although many silos were distributed to farmer groups free of charge, they were also promoted through revolving credit funds and payments in grain (Annex 2, Project 15). By all

BOX 3.2. Farmers' benefits from using the silo— Central America

- The benefits consisted of improvements to family food security; reduction in postharvest losses; increased income from selling grain at a later date; improving farmers' negotiating position with middlemen (more of a sellers' market, as there was no rush to sell); savings from not having to buy back in the lean season; improvement in the position of women within the home economy (reducing drudgery etc.); and improvement in health, hygiene, and general household welfare; easing the diversification into profitable cash crops; and production of (high-yielding but less pest-resistant) hybrid maize.
- The adoption of the silos not only benefited the owner's family but also nonowners within the same rural communities. More grain was being stored and sold locally *libreado* (a pound at a time). This advantage would be of great significance in Africa, where even in surplus-producing areas, a small minority of farmers normally produces most of the surplus, and most farmers produce insufficient for their annual needs. When farmers have more grain to sell in the lean season, it tends to force prices down in favor of the consumer.

Another important advantage of the silo was the convenience factor. Despite the poverty of most farmers, the simplicity of the structure was a major attraction. It could be purchased "ready to use," without the need for the farmer to find the materials himself; it did not require much maintenance and was easy to use.

Source: Coulter and Schneider (2004).

accounts, the extension in Africa was not without its problems. In Mozambique, the dissemination failed due to an inadequate capacity for local fabrication. In Malawi, metal silos of 250-kg, 500-kg, 900-kg, and 1.9-ton capacities were made available, but the largest capacity supplied wouldn't fit inside most houses, and costs were considered high (US\$120–450). Farmers were given very little training in use and were reliant on extension services to fumigate grain. Consequently, many of the silos that were supplied free of charge were not used. The main reasons for this would appear to be (i) security issues—farmers want grain to be inside their house; (ii) the need for fumigation treatments to

be done by the extension services; and (iii) the silos were targeted at the community, not the individual. The farmers' main approach to storage was to have bags in their houses, which they consider cheaper, more convenient, and more secure.

Metal silos clearly do offer continuing opportunities for the reduction of PHL in SSA. CIMMYT is currently undertaking a pilot research study investigating technical and social issues and promoting the silos in Malawi with CRS and with World Vision in Kenya (Kanampiu 2009). It appears that there is still considerable potential for extending metal silos in Africa. However, it is important to take into account the lessons already learned in SSA and those learned by the PostCosecha project in Central America (Box 3.3).

Bags and other storage structures made of plastic have the advantage that they can be made airtight (hermetic). Under such conditions, biodeterioration can be slowed. One such method currently under extensive promotion is the use of "triple bagging" for cowpea storage, although it could be adapted for grains.

The triple-bagging technique was developed as an effective hermetic storage method in Cameroon (Kitch and Ntourkam 1991), using two inner bags made of 80 micron polyethylene and one outer, more durable bag to help protect against damage. Well-dried cowpea fills the first bag, which is tied shut securely using string. The first bag is placed within a second bag, and this is closed securely. A third bag is used to enclose the first two and to protect against damage. Clear plastic bags are recommended so that the cowpea can be inspected easily for any signs of insect attack. It is also recommended that the bags should remain sealed for at least two months after they are filled, and after they are opened, they should be resealed quickly to prevent entry of pests. The bags must be kept safe from rodents that might make holes in them and so break the seal. The Bill and Melinda Gates Foundation is currently funding a large regional West Africa food-security project (Purdue Improved Cowpea Storage), which is being implemented by World Vision and Purdue University with assistance from the National Agricultural Research Institutes. The project is extending hermetic triple plastic bags of 100-kg capacity, each costing ~US\$1.8, to 12,660 villages throughout Niger, Mali, Chad, Ghana, and Senegal (Schmidt 2009). In addition to supporting extension and farmer training, they are linking with the bag manufacturers and retailers to enhance long-term access. They have found that the bags are easily accepted by farmers, provide a very high level of insect control, and can be used for 3–4 years before they become too damaged. However, bag quality is an issue; the seams

BOX 3.3. The lessons learned in metal silo promotion in Central America by the Swiss agency for development and cooperation (SDC) PostCosecha project

1. *Willingness to buy* the silo is a powerful indicator of demand. The measure brings together the various benefits that the farmer is deriving from the silo, which are difficult to calculate exactly in cost-benefit terms. For this reason it was advantageous to have a major component of unsubsidized sales, as this provided the program with objective feedback on farmers' own valuation of the benefits derived and of their willingness to invest in postharvest improvements.
2. The need for a long-term approach to marketing that involves (i) attention to all aspects in the marketing mix (product, price, distribution, and promotion) and quality control; (ii) focusing effort initially on a limited geographical area; and (iii) the involvement of many collaborating transfer institutions. *It takes considerable time for farmers to evaluate and adopt new storage technologies*, and strong follow-up is needed to ensure that the structures are being correctly made and used. If this is not done, the whole concept can easily fall into disrepute. This provided a rationale for SDC's 20+ year commitment to the PostCosecha project. Typically, such systematic long-term approaches are lacking in postharvest initiatives in Africa.
3. The silo lends itself to quality control better than most other structures do, given that this function can be focused largely on a limited number of artisans—650 at the last count, as opposed to hundreds of thousands of adopting farmers. Standardization of the silo in terms of both design and a small number of standard sizes made training and quality control much easier.
4. The silo was mainly used to store grain for home consumption, rather than for marketable surpluses that needed to be disposed of in wholesale quantities, due to the low speed of unloading through the outlet spout.
5. The involvement of the transfer institutions was very beneficial in building up demand for the silo and developing artisans' supply capabilities but may have diverted the artisans from developing their own markets directly with the farmers. It would appear that for sustainability, *there is a need for a move from an "aid-driven" approach to an entrepreneurial and marketing-oriented approach*. However, there is a continuing need for public investment in promotional activities that entrepreneurs cannot be expected to carry out individually.
6. Experience showed that it was possible to train small farmers to treat their grain safely with fumigant (phosphine) when using the metal silo.

Source: Coulter and Schneider (2004).

are particularly crucial in obtaining a hermetic environment. Timely delivery of the bags is critical, as is thorough training of all partners in how to fill, store, and maintain the bags. The project has also recognized the need to ensure that distribution channels are given more attention to help commercial sustainability after the post ends; in Niger, the project distributed free bags to five households in each of more than 5,000 villages as part of the promotion activities, but other households have been buying the bags.

Also made available, instead of triple bagging, are hermetic sacks made of tough multilayer polythene material incorporating a gas barrier that restricts oxygen and water vapor movement. These hermetic sacks (Figure 3.4) are made to hold from 50 kg to 3 tons of grain or seed. IRRI has tested super bags that fit as an airtight liner in the existing woven bags used by the farmer. Studies with paddy storage in super bags in the Philippines demonstrated that farmers are able to

maintain seed germination viability for much longer periods, control grain pests without using chemicals, and maintain grain quality for a longer period. Hermetic sacks are apparently being traded in Africa (Table 3.2). It has been suggested that these cost around US\$40 per ton and can be reused two or three times (FAO 2010).

Plastic drums of all sorts, including water tanks, can be sealed and used as effective hermetic grain stores. In Namibia, the traditional termite-resistant mopane wood store has been reproduced in brown or blue plastic (Figure 3.5) by a water tank manufacturer. The cost of these stores is US\$200, and the manufacturers (in 2005) were looking for agricultural bank support to make loans available to would-be purchasers.

Pest management in storage

Grain can become infested by insect pests prior to storage or during storage if the store structure is not insect proof. A

FIGURE 3.4. IRRI super bag (the gas- and moisture-proof liner)



Source: Rick Hodges.

range of options to provide protection during storage is open to smallholder farmers not able or willing to adopt an insect-proof, hermetic store.

The implementation of good hygiene and the training of farmers to calculate the cost and benefits of the pest-management

TABLE 3.2. Hermetic sacks and hermetic large-scale envelopes used in Africa

SMALL-SCALE HERMETIC SACKS		LARGE-SCALE HERMETIC ENVELOPES	
Ethiopia	Seed and coffee	Sudan	Wheat
Kenya	Maize and coffee	Kenya	Maize
Uganda	Seed and coffee	Uganda	Maize
Rwanda	Coffee	Rwanda	Maize, sorghum, rice, beans
Malawi	Maize	Tanzania	Maize
Ghana	Maize	Ghana	Maize
Zambia	Maize	Nigeria	Maize
		Sierra Leone	Sorghum
		Senegal	Peanut seed

Source: Information from Grainpro Co.

options open to them at time of harvest are potentially significant contributions toward limiting PHL. This advice is within the remit of the government and nongovernmental organization (NGO) extension services yet is rarely promoted.

FIGURE 3.5. Plastic granary (left) and the traditional mopane wood model (right)



Source: Rick Hodges.



It would seem an ideal subject for primary and secondary school curricula, although it would have to be adapted for prevailing storage conditions.

The judicious use of synthetic insecticides offers farmers storing grain a potent means of protection against storage pests. The best example of this has been the campaigns against LGB, in which shelling of maize cobs, the admixture of an insecticidal cocktail (mixture of organophosphorus and synthetic pyrethroid), and storage in sacks or other containers has limited grain losses.

LGB is a major storage pest that attacks maize and cassava in storage. The pest was accidentally introduced into Africa (Tanzania, East Africa, West Africa) during the late 1970s, where it has spread rapidly. Trade and food relief are the critically important routes through which LGB spreads. The pest causes significant losses to maize, making storage impossible over long periods and thereby compromising food security and lowering the quality of marketed grain. The potential benefits of controlling LGB include reduced losses, improved quality and nutritional value, reduced need to sell early when prices are low, reduced disruption to trade, and reduced need to secure alternative food to compensate losses. All this has prompted huge investments to deal with LGB (Annex 2, Project 11). An impact study by DTZ Pieda Consulting found that the benefits accruing to Ghana and Tanzania have more than exceeded the costs incurred by DFID (Goletti and Wolff 1999). Total benefits should have been higher if figures from Benin, Kenya, and Togo were included in the calculations. Total expenditure to control this pest amounted to £15.2 million at 1998 prices, while the gross savings for Tanzania and Ghana amounted to £17 million, a figure that would more than offset the total expenditures of donors, also giving a benefit-cost ratio greater than unity (Goletti and Wolff 1999). It is worth noting that the benefits of this intervention will continue to accrue in future years while the costs remain the same or are not incurred, so the benefit-cost ratio should increase with time.

However, synthetic insecticides are falling out of favor for environmental and health reasons, and the future is likely to rest more on other approaches such as good hygiene, hermetic stores, and the application of alternatives to synthetic insecticides such as diatomaceous earths (see below). It is also possible that the insecticides derived from local plant materials and used traditionally by farmers in certain areas can be introduced to those groups that do not already use them, in much the same way as the use of mud silos can

be introduced to groups who traditionally use less efficient storage methods.

The use of diatomaceous earths (DEs) for the protection of stored grain against insect infestation has a long history in China, but it is a novel approach in Africa (Annex 2, Project 12). DEs are the fossil remains of aquatic plankton and may be mined and then refined for use as storage protectants. DEs are nontoxic to mammals and therefore safe to mix with food (Quarles 1992). However, when particles of DE come into contact with insects, they absorb wax from the insect cuticle, causing water loss, desiccation, and death (Ebeling 1971). They have been shown to be as effective as the synthetic conventional insecticide, actellic super dust, in limiting insect damage on farm-stored maize, sorghum, and cowpea grains in Tanzania and Zimbabwe for periods of eight months (Stathers et al., 2002a; 2002b; 2008). However despite significant research activity, the bottleneck of registering and commercializing DEs in SSA has not yet been overcome for either imported or locally available deposits of DEs. Many DE dusts are now available commercially and are registered for use as grain protectants in Europe, United States, Australia, China, Japan, and the Middle East. The potential remains for private sector companies in African countries to register the use of DEs for stored grain protection, to exploit their own deposits of DEs as environmentally acceptable alternatives, and to import substitutes for synthetic insecticides. The incentive to do this may increase as pressure is brought to bear to remove existing organophosphate-based products. However, it should be noted that DEs from different sources vary in their efficacy against insects (Katz 1991; McLaughlin 1994; Korunic 1998; Mvumi et al. 2006); therefore, blanket recommendations for local deposits of DEs prior to testing their efficacy would not be valid.

Exposing grains to heat treatment could have very beneficial effects, although to date the process is applied only to pulses. Traditionally, farmers have exposed pulses to sunshine at various intervals after storage, and this has helped reduce losses from mold and insects by lowering moisture content and by driving off some adult insects and perhaps even killing some in the developmental stages. Sunning common beans (*Phaseolus vulgaris*) is often practiced in several parts of Uganda and Tanzania with a frequency of every 1–4 weeks; it is usually combined with other types of treatment such as admixture of botanicals, ash, or even soil (Giga et al. 1992). Such treatments would be expected to be

effective for grains, but the larger quantities involved may impose excessive labor requirements.

Although sunning is advantageous, it does not normally result in a high enough temperature for a sufficient period of time to kill all the insects. However, if cowpeas are held at 65°C for about 5 minutes, all life stages of *callosobruchus maculatus* can be killed; at 57°C, all stages can be killed in about 1 hour (Murdock and Shade 1991). To achieve lethal temperatures, pulses need to be solarized in a solar heater—this can be as simple as placing the cowpeas on an insulating layer, covering them with a sheet of translucent plastic, and weighing down the edges with stones. The solar heater is kept in the sun for at least 5 hours and will kill all insects. However, if the cowpeas are to be used as seed for planting, this may not be an appropriate procedure; there is some evidence that it can reduce germination rates by up to 20 percent. Plastic sheeting solar heaters have been successfully extended in Cameroon (IRA Cameroon/Purdue CRSP project) as well as in Uganda and northern Ghana (Crop Postharvest Programme, DFID project). An alternative to plastic sheeting is to use a solar heater constructed from corrugated galvanized iron; this can be used for larger quantities and is more durable than plastic sheeting, so may be a more cost-effective option in large-scale operations. The larger-scale option may be appropriate for the treatment of grains.

Large-scale storage

Innovations in larger-scale storage have focused on the use of hermetic containers that can control insect infestation without the need for fumigation. Large, sealed, plastic envelopes

closed using gastight zip fasteners are used in a wide range of African countries (Figure 3.6). Envelopes of various capacities are available, although in Africa they are commonly of 50 tons. A cooperative in Rwanda has been supplied with 50-ton units, but experience has shown that these types of storage are not used effectively without good staff training. While these are undoubtedly good stores, the benefits of being hermetic are lost if they are opened frequently for grain removals or deposits; and if they are less than 75 percent full, the plastic walls are slack and prone to rodent attack. The cost benefits of this system against conventional methods have not yet been demonstrated, although their use is favorable under some circumstances (Annex 2, Project 17). It is suggested that they cost from US\$180–\$220 per ton, depending on size (FAO 2010).

In northern Ghana, large, high-density polyethylene water tanks (3,000–4,000 liters) were adopted by TechnoServe in a pilot scheme for the storage of cowpeas for small traders or farmer groups. An outlet was added at the base of the tank for off-loading, and the tanks were placed on platforms and provided with shade from the sun. The cowpeas loaded into the tanks were fumigated with phosphine, and good preservation was achieved. Further testing was recommended to determine whether the hermetic properties of the tank were reliable for the killing of insects without the need for fumigation. Although used for cowpea storage, this system would be expected to work equally well with grains.

The government of Niger stored 10,000 tons of cowpeas in hermetic triple plastic bags in 2008–09 for strategic food reserves. Clearly, the triple-bagging method can have

FIGURE 3.6. Hermetic grain-storage envelope sealed shut with a gastight zip in Rwanda



Source: Rick Hodges.

applications in large-scale storage, as can super bags. It would be worthwhile to examine the cost benefit of using sealed bags for grain preservation in large-scale storage against the use of conventional pest management with fumigation.

SUMMARY OF THE CRITICAL TECHNOLOGIES AND PRACTICES AVAILABLE FOR PHL REDUCTION

Examples of a range of technologies that can be applied at various points of the value chain are discussed above and are also presented in Annex 4. Some of them have already seen wide and successful adoption; others less so—or are as yet unused. In summary, the current opportunities for smallholders to reduce their PHL are the following:

- **Crop varieties:** grain varieties with better postharvest characteristics should be developed. It is important to strive for grain varieties that have greater resistance to damage from insect pests and fungi. However, to date, little progress has been made despite many years of research. Genetic transformation may offer opportunities, but this may not be acceptable in many SSA countries.
- **Harvesting:** use of minicombine harvesters may offer opportunities to farmer groups to reduce labor requirements and gather a full harvest. The costs of the technology are high, so the benefits may only apply where the crop is sufficiently valuable, for example in SSA's expanding rice industry. Currently, in most situations it is unlikely that changes can be made to traditional smallholder harvesting methods.
- **Drying grain:** use of various drying equipment reduces physical losses and potential contamination with mycotoxin (Box 3.4). The type of equipment employed depends on the scale of farm production; tarpaulins can be used to cover small quantities of grain in damp weather, whereas larger quantities may be put into drying cribs or processed in various types of mechanical dryers. Mechanical dryers would be more appropriate for farmer groups than for individuals.
- **Threshing, shelling, and winnowing of grain:** use of mechanized rice threshers/winnowers and maize shellers can speed up postharvest operations and deliver improvements in grain quality and quantity. These may be hand powered or motor driven and have become more relevant as labor shortages increase. Access to motor-driven equipment would need to be through farmer groups or supplied as part of contract farming arrangements.

- **Storage structures:** a variety of different storage structures are available according to scale of operation and may either be open to air exchange or airtight (hermetic). Stores offer shelter to the grain, and in addition, hermetic stores by themselves also prevent pest damage. Grains can be stored in sacks of various types on both a small and large scale. For medium- or long-term storage, hermetic sacks may be used when benefits outweigh costs. In other situations, traditional mud stores (as well as more modern plastic or metal silos) may significantly reduce the PHL of smallholders. Such stores may be hermetic or at least sufficiently sealed to prevent pest access to grain.

If these technologies and practices are to be given a reasonable chance of successful adoption, they must first be carefully evaluated from a technical, economic, and social perspective and adapted as necessary. The success of such technologies is also heavily dependent on smallholders having knowledge, skills, and awareness of grain postharvest management for loss reduction.

INSTITUTIONAL ARRANGEMENTS FOR GRAIN MARKETING

Improved postharvest technologies and practices may have limited effects if their introduction does not confer obvious benefits such as a financial reward for improved grain quality,

BOX 3.4. Good storage hygiene is the single most important element in maintaining grain quality and reducing PHL during storage

Poor storage hygiene can lead to the perpetuation of storage problems from one season to the next.

The principles of store hygiene are essential to good pest management, and smallholders across SSA would make significant progress in limiting PHL by observing these practices. If stores are sufficiently sealed to prevent pest access, prior treatment of grain by solarization will disinfest grain and so prevent pest development. In stores that do not prevent pest access and where grain stocks are to be retained for more than three months, a means of pest control is required. This may be achieved by admixing synthetic insecticide or by the use of non-toxic alternatives such as diatomaceous earths, as these are available for use in the countries. In some situations, it may also prove appropriate to use insecticidal material derived from locally available plants.

Source: Authors.

prevention of significant loss in household food security, or nutritional value. Often, better financial rewards follow improvements in marketing channels, and these may be achieved by encouraging the formation of farmer groups to achieve collective marketing and market institutions. The pros and cons of cereal banks as a form of collective marketing aimed at improving food security were discussed in the previous chapter. In this section, an analysis is presented on market institutions such as inventory credit and WRS, and other recent innovations in marketing systems in SSA.

Warehousing is a collective term for WRS and related inventory credit, which introduces liquidity into grain supply chains and can help reduce PHL. Warehousing creates a framework of accountability between the different parties involved (depositor, warehouse operator, and financier) and for this reason is usually effective in reducing PHL, inasmuch as these are significant prior to the introduction of the warehousing system. These institutions support value-chain development by setting standards, implementing quality control, and offering storage facilities and credit. Farmer groups that supply warehouses within the WRS have a quality-conscious “customer,” and the better-quality grain produced in response to this incentive will produce lower PHL and higher income. Further along the marketing chain, the storage capacity of traders is frequently inadequate in terms of both volume and the ability of their staff to manage grain stocks to maintain quality; licensed warehouses used by a WRS potentially can remedy this problem.

WRS are usually based on licensed commercial warehouses where grain can be deposited—provided it meets stated quality grades and a minimum quantity (usually 10 tons or more). The warehouse operator issues warehouse receipts for deposits; these receipts may be transferable. The operator also guarantees delivery of the commodity described on the warehouse receipt and is liable for any losses incurred. A transferable receipt may be transferred to a new holder (such as a lender, if the stored commodity is pledged as security for a loan) or to a trade counterpart. Hence, depositors requiring short-term financing can obtain an advance representing a percentage of the prevailing market value of the commodity from a bank, using stored commodity as collateral. The depositor can wait until such time as market conditions are conducive to sell the stored commodity. A depositor has to pay storage and, where applicable, collateral management fees. Outside of the Republic of South Africa, the development of WRS in the African grain sector has been slow due to the relative informality of the trade and the difficult policy environment of a politically sensitive

food crop (Coulter 2009). High-value export crops, such as coffee or cashew, have fared better. Three main warehousing approaches have been implemented: private, public, and farmer-focused. Coulter (2009) discussed their benefits and achievements in a recent paper. His results are summarized below.

Private warehousing has individual clients but no obligation to receive deposits from the public in general. It usually operates under tripartite agreements consisting of a bank, the borrower, and a collateral manager, such as a local subsidiary of an international inspection company. They have not been widely used for grains, with the exception of rice. They are common in South Africa where financial markets are well developed. It provides local enterprises with crucial access to credit, helping them compete against vertically organized multinationals. The main limitation of private warehousing with regard to grain supply chains in Africa is that it has little involvement with farmers and small traders because of the large fixed cost that is required.

Public warehousing, where operating companies receive commodities from whosoever wishes to deposit (notably farmers), can be highly effective in enhancing grain value chains. For example, public warehousing through silo certificates was crucial to the successful liberalization of grain and oilseed marketing in South Africa. Various other countries have started implementing, but progress is slower due to the relative scarcity of larger scale players, informality of commodity chains, lack of bank involvement with grain value chains, and—above all—a difficult policy environment with politically sensitive food crops. The most immediate opportunity seems to lie in Eastern Africa (particularly Kenya), where trading structures are closer to those in South Africa and where there are prospects for effective regulatory arrangements.

In the case of farmer-focused approaches, small groups of producers or producer organizations store exclusively for their members. Basically, there are two main variants. The first is the microfinance-linked approach, where stocks are held in the name of each individual farmer and finance is provided by a microfinance institution, often with bank re-financing. Such schemes are characterized by high levels of repayment and are already having a positive impact on commodity chains and local food security; however, with rare exceptions, the scale of impact is limited thus far. For example, with paddy rice in Madagascar, the approach has had a significant impact on agricultural lending and national price stability. The second variant is the cooperative approach, where a bank finances collective storage and marketing of grain. Farmer-focused

approaches have been in use in Mali, Tanzania, Niger and Togo.

It is clear that a WRS can overcome a range of constraints, including long marketing chains, lack of trade finance, weak bargaining position of producers, lack of adequate market information, a slow and costly bulking process, lack of quality premiums at the farm gate, wide distribution margins, and large price risk. At the same time, the enforcement of commodity grades associated with the WRS can help traders access more lucrative international and regional markets. There are several donor-funded WRSs in SSA, but these have yet to show their full potential.

In most cases studied, while the theoretical benefits of WRS are clear, they have rarely functioned as they should have. The concept, while simple and appealing, is not mirrored by the demanding requirements. In most places they are set up as a storage facility managed by insufficiently skilled managers with inappropriate government or donor support and are characterized by subsidies and price-distorting policies. The basic rationale for WRS is risk management, and it needs to be operationally sustainable—which requires considerable throughput in order to offset the high fixed costs of running warehouses. Its scale and versatility allows public warehousing to play a larger role in enhancing the efficiency of the commodity value chain. However, donors occasionally support these systems on the condition that the effort is targeted at smallholder farmers, which reduces their efficiency (Box 3.5). While it is desirable for smallholders to have access to these public facilities, they need to do so on commercial terms, and producers would normally have

BOX 3.5. Warehouse receipts systems

Some of the most obvious failures in concept and delivery have been commodity exchanges and WRS that have been set up quite often by donors rather than by the private sector. Although these are both ideas that work well in formalized market situations and have great merit in the right situation, they have serious flaws when they are pushed into largely informal market places through political pressure and outsized subsidies. These institutions will likely fail when support is withdrawn. These are typically multimillion projects that do not work, as the marketing environment is not sufficiently developed to support them. Even if they did work, they would not help smallholders, which they are often claimed to do.

Source: Dr. Shaun Ferris (Sr. Technical Advisor, CRS).

to be in organizations in order to deposit quantities that are financially viable to the warehouses. The implementation of WRS requires the careful design and concerted efforts on various fronts, including predictable price policies that do not compromise the enterprise's commercial orientation, with the dual objective of poverty reduction. Specific examples of WRS schemes are described in Annex 7.

Inventory credit can be seen as an alternative approach to the cereal banks discussed in section 2; however, ensuring that the poorer members of the community benefit from it is a challenge. It has been instituted with varying degrees of success. Inventory credit is a means of offering stocks of commodities as a physical guarantee for a cash loan. This approach creates links between financial institutions and the trading sector. Inventory credit schemes can operate locally with small volumes and microcredit and can be based around producer or farmer organizations; they have a business approach as opposed to a social approach. An inventory credit scheme can also be upgraded into a WRS, involving larger volumes of grain in professionally managed warehouses, where the receipts are negotiable financial instruments that may be traded several times before the stock is delivered from the warehouse to the receipt holder. The larger systems may be accessible to farmer groups and producer associations, provided the minimum deposit size is not too great (e.g., 10–100 tons; see Annex 7 for specific examples of inventory credit schemes). The way forward for inventory credit schemes and WRSs in East and Southern Africa has just been reviewed in detail by Coulter (2009).

There have been several other innovations in grain marketing in recent years, notably the WFP's Purchase for Progress (P4P) initiative, which aims to re-orientate WFP's procurement process toward local and regional sourcing. In this regard, P4P encourages local farmer groups and agro-industries to supply grains and other agricultural products according to WFP specifications. There are many technical, logistical, and business challenges for farmer groups to meet the WFP standards; nonetheless, the P4P initiative offers an important and lucrative market opportunity to those farmers and companies that can meet WFP requirements.

The private sector has also been proactive in developing a number of innovative marketing arrangements. The East Africa Grains Council (EAGC) draws membership across the value chain: producers, traders, and processors. Service providers are associate members. The council operates as a nonprofit, nonpolitical, nondenominational organization that prepares, disseminates, and promotes the

exchange of information on matters affecting the regional grain industry. Among its activities, it supports regional trade and provides training in postharvest handling. The Grain Growers Association of Kenya (CGA) has a membership consisting of smallholder farmers who join through farmer groups, medium-scale farmers, large-scale farmers, and other institutions affiliated with the agricultural sector. CGA provides a number of services to farmers who lost the support of government following market liberalization: extension services through associate members such as input suppliers and financial institutions, training in postharvest handling, and support to collective marketing. CGA is aiming to set up village storage satellites, each equipped with facilities (scale, moisture meter, and bag sticher) for receiving grain from farmers. Investment in the satellite store systems and the marketing systems around them would also create incentives for farmers to improve quality and reduce PHL.

Transferring risk away from smallholders is aided through the provision of integrated services. An innovative approach to support farm improvements has been piloted by Premium Foods in Ghana. The company has in place an integrated model for grain handling, consisting of an agribusiness center that hosts a dryer, sheller, and storage facilities and is linked to farmer organizations, banks, and other stakeholders such as business service providers and input suppliers. The farmers pay for extension services and receive training and capacity building. Farmers deliver their harvest to the agribusiness center before it is dried. The center processes and sells the grain and pays off loans provided to the farmer by the input supplier. The center serves as the “change driver” as it becomes the core of a sustainable system through which provision of technical assistance, training, and finance to farmers can be facilitated. Transferring the responsibility of grain drying to the center reduced the time required to dry grain to only three days, which results in better quality and lower PHL.

4. RESPONSES TO PHL REDUCTION

Early approaches to supporting postharvest improvements concentrated on making technological improvements to discrete components of the value chain in isolation from one another. Over the past decade, the rise of global and regional supply chains and the renewed emphasis on efficiency and compliance with quality and food safety standards have spurred a major paradigm shift in the way the postharvest system is conceived—from a series of individual components to an integrated system linking the producer and consumer. It is postulated that adoption of this approach and the opportunities it presents can lead to improved systemic efficiency; greater food safety and quality; and a clearer idea of the gaps in the ways the different chain functions are performed, who are the various participants along the value chain, and the benefits recurring to them. The challenge for postharvest policy is to ensure that improvements in postharvest system upgrades along the value chain benefit the majority of participants. *This chapter reviews the past government and donor approaches to support postharvest improvements, and lays out the background for determining requirements of future successful operations.*

During the 1960s and 1970s, development agency support to agricultural programs emphasized production improvements and support to public sector agriculture marketing and distribution systems. As was discussed in the previous section, the impacts of market reforms undertaken during the 1980s and 1990s on smallholders and the marketing and postharvest systems have been critical. They also have had significant impacts on the approaches applied by development partners to support the agriculture sector, including support to postharvest improvements. The range of approaches has expanded from those concerned only with solving constraints to farm productivity—farming system-based approaches—toward broader strategies focusing on the performance of farmers and other actors within the context of liberalized markets for inputs and outputs.

These developments have translated into a wider range of options applied by development partners and private actors to achieve objectives for reducing PHL. These include

a range of approaches, from those based on single-entry-point interventions to those that understand postharvest as a “system,” with opportunities to achieve postharvest efficiencies throughout the value chain. The typology used here to characterize the range of approaches to support postharvest improvements distinguishes two main types of approaches: those focusing on technological improvements or “technology push” approaches; and those relying on the market, as the driving force to promote chain upgrades and characterized here as “chain-wide” approaches. Although a chronological order can be identified for the emergence of these approaches, both types of approaches are currently applied to support postharvest developments (Table 4.1).

The so-called *technology-push approach* targets improvements at discrete points along the chain by applying a specific technology or marketing arrangement to address an identified constraint that results in significant postharvest losses. Many of these types of interventions have traditionally focused on removing constraints at the farm level (through individual or collective action); however, with the increasing focus on “farm-to-fork” improvements, the entry points for support have expanded to include improvements downstream in the chain. Several single-entry-point interventions were discussed in the previous chapter, including the very successful introduction of metal silos into Central America (Annex 2, Project 14) and the triple bagging of cowpeas, which is the subject of a current intensive campaign in West and Central Africa (Annex 2, Project 20). Further evidence of the technology-push approach comes from the Kapchorwa district in Uganda, where the timing of the harvesting and rainy seasons prompted the introduction of mechanized harvesting/cleaning equipment to reduce losses for wheat (Annex 2, Project 9).

A slight variation to the technology approach, also focusing on single-entry-point interventions at the farm-level, has been implemented by several development partners. For example, in the early interventions of the FAO Action Program for the Prevention of Food Losses (PFL) Program, which was established in 1977, the focus was overwhelmingly technical,

TABLE 4.1. Chronology of postharvest-related interventions and approaches in grain chains

YEAR	EXAMPLE OF TYPE OF INTERVENTION	DEVELOPMENT AIM OR THEORY	TYPE OF INTERVENTION APPROACH
1970s	Community stores Central storage (silos) Improved on-farm storage	Food self-sufficiency import substitution	Single-entry-point/single technology
1980s–1990s	Cereal banks Improved on-farm practices	Structural adjustment Farming systems Participatory approaches	Single-entry-point/multiple interventions
2000s	Promotion of technologies and practices at various stages of the supply chain Market information systems Commodity exchanges Warehouse receipts	Linking farmers to markets Agricultural commercialization Export orientation Liberalized trade Innovation system	Market-based approaches, increasingly with a value-chain focus (both with single or multiple entry points)

Source: Authors.

utilizing the assessment of postharvest losses at storage and the transfer of improved on-farm storage technologies. The support expanded later to more integrated assistance, including the transfer of improved farm-based technologies and practices (e.g., sorting, drying, pest control, farm storage, etc.). IRRI, for example, has been implementing initiatives under this type of approach for rice in Southeast Asia (Annex 2, Project 18) and more recently in Africa (Project 19) through public and private partnerships.

During the mid-1990s, market-oriented approaches emerged focusing strongly on the market as the driving force for postharvest improvements and base their success on good business practice and on facilitating farmer linkages to markets. This “system approach” to tackling postharvest issues emphasizes the links of on-farm activities with other operations within the food and commodity chain, while placing the chain within wider socioeconomic, business and political context. Under this approach, value chain coordination is a clear component of the support. FAO’s Global Program on Postharvest Loss Reduction: Linking Farmers to Markets, established in 2002, was set up with this market-based focus. This approach is well illustrated by the Kenya Maize Development Program (Annex 2, Project 25), which combines improved yields, provision of training aimed at improving production practices and business skills, collective action for crop marketing, and provision of market information. The adoption of this approach can lead to greater system efficiency; reduced PHL (both physical and opportunity losses); and a clearer understanding of the various participants along the value chain, the opportunities for collaboration, and the benefits derived through improvements in the postharvest system.

The vast majority of grain-based interventions in Africa have focused on improved production systems; only recently

have they focused on supporting sustainable participation of farmers in markets. Addressing PHL (physical) has, in most cases, been a spill-over effect. Overall, in cases where interventions have specifically targeted PHL reduction objectives, they have done so by focusing on improved handling and facilitating adoption of specific technologies, particularly for storage and drying. Examples were presented in the previous chapter, ranging from the provision of plastic or metal silos, jute, super or hermetic triple plastic bags for storage, tarpaulins for drying, and so on.

Lessons learned from failed attempts to push for postharvest improvements by only focusing on technical aspects have highlighted the limitations of this approach. For example, early experiences of the FAO/PFL program in the 1970s–1980s, implemented with a focus on farm storage among subsistence farmers, presented very low adoption rates and proved to be unsustainable. The effectiveness of technology to reduce PHL is important; however, a critical factor in creating impact is not only the technology per se, but also its relevance to the situation, its acceptability, and favorable costs and benefits, which can be determined by factors and constraints downstream on the chain—not necessarily at the farm level. Understanding not only the ability of farmers to overcome constraints related to technical know-how but also the local availability of materials, financial resources, and overcoming market constraints is critical. Farmers do not accept new postharvest technologies unless the benefits exceed the costs by a margin sufficient to justify risks involved *and* unless they are culturally acceptable. A more detailed review of the benefits, costs, and degree of adoption for a range of postharvest technologies is presented in Annex 3.

Establishing PHL baselines is important for making a proper assessment of postharvest-related problems and their

underlying causes. *PHL are most often reflective of problems occurring along the chain steps; therefore, they provide indications of functional and operational performance gaps.* When proper baselines are not established and the magnitude of the problem is poorly understood, it is often risky to embark in the promotion of postharvest technologies, as they may well not be the main constraining factor. In the Central African Republic, for example, the Postharvest Food Systems project was found to design its activities based on the assumption of high storage losses. Later on, this assumption proved to be invalid for the target area and the selected crop.

Ensuring the *economic acceptability and affordability* of the technology or practice being promoted is critical to its success. Farmers and communities must produce a sufficient saleable surplus of grain to allow for investment in new technologies or approaches. Thus, scale of production will determine the options for change and the type of technology that could be adopted. In northern Zimbabwe, for example, the project looked at replacing the timber posts of raised mud granaries with PVC pipes filled with concrete. These pipes, however, were considered expensive by the majority of farmers and, furthermore, were not always locally available. As a result, the project was ineffective. Another example is from Malawi: the costs of small metal silos being promoted there were higher than anticipated and beyond the reach of most small-scale farmers.

Although a *lack of financial incentive and difficulty in obtaining credit* are among the important causes of PHL, once the financial framework is in place, the lack of technical knowledge of farmers becomes a limiting factor. Lack of skills can be addressed through the provision of appropriate vocational training to those who would engage in the postharvest sector, whether through public or private sector interventions. The development and adaptation of postharvest equipment and the training of personnel in postharvest techniques offer a direct route to PHL reduction. Technical adaptations can be achieved through the support of technical centers, training activities at farm shows, and farmer field schools. These can introduce improvements in postharvest methods at all links in the chain—especially in the areas of on-farm handling, preparation for market, and small- and medium-scale agro-processing. Vocational training in postharvest technology is essential for the supply of personnel to operate in all stages in the supply chains and present career prospects with the public and private sectors.

Technologies and practices should also be *culturally acceptable*. In southern Malawi (and many other countries), farmers

prefer to keep their stored grain inside their houses because of possible theft if the granary is outside. However, the small metal silos project in Malawi (funded by FAO and the Malawi government), which planned to distribute more than 5,000 subsidized metal silos to farmers for storage of maize, had not taken this issue into account. Additionally, the estimated cost of these small silos was higher than anticipated in the proposal and therefore beyond the reach of most smallholders. In Kapchorwa, a district of Uganda, the promoted silos for drying and storing grains were not taken up by farmers because many of them were better than most farm houses. Culturally, farmers could not accept an on-farm storage facility that was better than their house.

The timeframe for adoption of PHL interventions must be considered early in the planning process if technologies are to be successfully introduced and appropriate timing for the withdrawal of project support programmed. It is important that projects be planned over a time span that can realistically deliver a successful outcome. The very successful metal silo project in Central America (Annex 2, Project 14) was the result of more than 20 years of donor backing. Donors need to be convinced that their investment will not be wasted, and this should be based on sound analysis at the start and rigorous evaluation at key milestones.

Although technology adoption has been the main focus of many of the PHL-related interventions, with the transition to market-driven systems and greater reliance on the private sector, there is increasing recognition that postharvest technologies or innovations must be embedded within the context of value chains and must leverage their success by building synergies with the private sector. Focus must be placed on systemic interventions that improve the efficiency of the chain as whole, rather than as the stand-alone upgrades common in the past. More efficient postharvest systems will bring benefits not only to farmers but also to all other chain actors, including consumers. This calls for farmers to be better organized, act collectively, and acquire stronger group business and marketing skills in order to participate effectively in the new value-chain context.

Although value chain analysis has emerged as a useful tool to analyze functional and operational gaps along the chain (and to understand the incentives for upgrading), it has been poorly used in the cereal value chain analysis in Africa to leverage postharvest improvements. Recent value chain analysis undertaken for maize value chains in the region has focused on the understanding of marginal gains recurring to the different actors, with few efforts made to link this analysis to functional and/or operational gaps and their

implications on the magnitude of postharvest losses (see USAID 2005; 2008). A more recent study of marketing constraints in regional value chains in Tanzania, Uganda, and Kenya is a close approximation of the use of a more holistic analysis, including opportunities for postharvest improvements, although still very much focusing on losses at the farm level (World Bank, 2009). Thus, the recent emergent emphasis on value chain analysis represents an opportunity to revisit many specific value chains and re-analyze them from the point of view of the impact of PHL on the chain as a whole. In particular, it could prove a valuable tool for policy makers to locate where changes in policy with regard to the postharvest system might have impact. It has been argued that for the future, projects should not be concerned with single issues but must take a value chain approach using a sectorwide team to develop products and solutions.

Many projects have achieved a measure of success in improving a specific aspect of a postharvest system. However, very few have achieved large-scale improvement, primarily because of a lack of commercial incentive in investing in and scaling up such initiatives. To ensure sustainable improvements in postharvest systems, the central role of the private sector must be recognized, and PHL-reduction strategies that provide economic incentives to those making the investments need to be developed. If chain actors are not willing to co-invest, it is probably an indication that there is insufficient economic incentive or that the intervention will only work with external support. Therefore, the utility of the value chain analysis lies in the possibility of better understanding entry points for leveraging PHL reduction objectives. Therefore, well-founded, single-entry-point interventions—“technology push” projects—can be successful, provided that (i) they respond to identified demands and opportunities for upgrading within the context of the specific value chain; (ii) the expected outcomes are well understood by beneficiaries; and (iii) they are well situated within the context of the dynamics of the specific value chain. This increases the chances of adoption and replicability.

As several authors have pointed out, it is not economical or even practical to aim for zero percent losses, but to seek a better understanding of acceptable loss levels for specific grain commodities, with specific production area and seasonal consideration, can be gained on the basis of cost-benefit analysis. This implies not only the establishment of proper baselines for PHL, but also a clear understanding of the effectiveness and applicability of proposed post-reduction strategies, including cost/benefit considerations and the

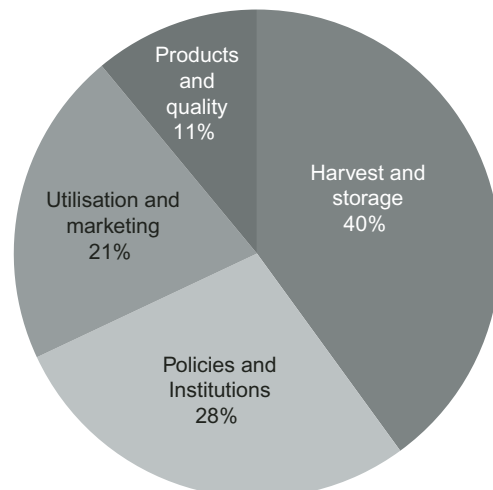
perceptions of stakeholders along the chain regarding their possibility for adoption.

The increasing importance of chainwide and holistic approaches to postharvest improvements is supported by the responses of the postharvest experts interviewed for this work (see Annex 1). The questionnaire asked these experts to recommend which future postharvest developments should be used to improve the quantity and quality of the grain supply from smallholders. For analysis, the responses were grouped into one of four categories according to the CGIAR postharvest framework (Arnold 1996). While targeting storage and harvesting issues directly remains an important area for future interventions to reduce PHL, this should be supported by better policies and institutions and improved marketing opportunities, including value addition. With growing urbanization and demands for better and safer foods, addressing product quality is becoming a key issue (Figure 4.1).

The respondents strongly believe that in the traditional area of PHL reduction, special attention should be given to the drying of grains, given the significant physical and economic losses that occur as a result of poor drying. For many SSA grain crops, proper drying can significantly enhance storage life and product quality, avoid product safety problems, and generate income gains by reducing both physical and economic losses.

Linking farmers to markets (by methods including improvements in transport infrastructure) and the policy environment

FIGURE 4.1. Recommendations for future interventions to improve the quality and quantity of grain supply in SSA (expressed in percent of suggested projects)



Source: Authors.

are key to providing incentives to farmers to invest and adopt PHL-reducing technologies. All-weather access roads to markets are essential in ensuring that crops do not have to spend extended periods in farm storage and in helping to reduce the high transport costs that reduce the incentives and increase the risks of trading a low-value commodity. Once suitable transport links are established, collective transport of grain becomes feasible through the hire of trucks by farmer groups. Similarly, improvements in legislation and the regulatory environment, which make it easier to establish agribusiness and agro-processing companies, often provide greater incentive to purchase drying and cleaning equipment than do free handouts of such equipment through NGO and donor projects. Farmers who have outlets to domestic or regional markets have the incentive to dry, clean, and store in order to benefit from selling larger quantities of more valuable products. In contrast, farmers who are far from roads and markets and produce the quantity that they need for self-consumption often find it cheaper to let the surplus go to waste than to store it.

Although the market can provide important incentives for adoption of postharvest technologies, given the high level of informality in grain markets in SSA, basic quality and safety attributes are frequently ignored, thus depriving farmers of incentives to invest in postharvest technologies and SSA populations from capturing the health benefits of improved postharvest methods that prevent and reduce product contamination (e.g., aflatoxin). Acute exposure to aflatoxins can be lethal, as exemplified by more than 150 deaths in Kenya in 2004 and 2005 that resulted from consumption of aflatoxin-contaminated maize. When the market does not reward these types of improvements (safety issues), there is a clear case for public action, including government engagement with private actors to facilitate adoption of improved postharvest technologies along the value chain.

Grades and standards provide important incentives for postharvest system upgrades, yet they have only a limited role to play in reducing postharvest losses given the current state of informality of grain marketing. This is particularly important in the case of safety standards. For example, several African countries have established standards regarding aflatoxin levels; however, their limited capacity to enforce them prevents widespread safety assurance and leads to chronic exposure. Furthermore, the establishment of aflatoxin regulations and standards has limited effects on protecting health in the region, as many farmers grow grains for their own consumption. The solutions to the aflatoxin problem, therefore, need to be holistic and multidimensional, with a better under-

standing of the contribution of postharvest improvements to aflatoxin management playing a pivotal role.

There is also the need to be more proactive in *raising awareness and building capacity* that will enable postharvest improvements to be effected and PHL reduced. This can be done through (i) inclusion of postharvest aspects in the curriculum of agricultural colleges; (ii) building farmers' capacity through development of diverse informal as well as formal training and information channels, including rural resource centers or village info kiosks, exchange visits, and farmer field schools; and (iii) harnessing the power of all types of media: radio, newspaper, television, and video. It should not be forgotten that SSA's rural communities' media also embody different forms, including drama, songs, and street theater, and these can be valuable resources for sharing information, although their power is not well understood by outsiders.

Very few countries in Africa undertake research on PHL other than for specific projects. This is reflective of the broader research community as indicated in a report by the University of California–Davis in 2009, which found that 95 percent of research dollars were directed at agriculture focused on production with only 5 percent of remaining dollars targeted on nonfarm challenges. Some countries have *postharvest research units*, but these are mostly concerned with grain storage. Where these units do exist, they are commonly in agricultural research directorates and far from policy makers. Policy needs to be informed by appropriate research, but there is a substantial lack of research capacity. Identified areas for research include investigating where losses occur and the best means of tackling them. There is a need for more basic research that would contribute directly to PHL reduction by, for example, breeding crop varieties that improve the shelf life of crops or have a lower susceptibility to postharvest pests. National research activities can be integrated into LAs to implement and coordinate innovations, as successfully done for several projects (see Box 4.1 and Annex 6).

Assessing diversity and gender roles is critical in determining the effectiveness of the proposed solutions to PHL. In SSA, women play a significant role in postharvest handling, processing, marketing, and household food security. In addition to gender, communities can be disaggregated by age, wealth, household composition, health status, etc. This diversity is important. HIV/AIDS and increasing migration (due to population growth, decreasing land sizes and fertility, climate change, urbanization, and associated employment opportunities) mean that in rural SSA, there are rapidly growing numbers of child-headed households, female-headed

BOX 4.1. Learning alliances for PHL reduction

A learning alliance (LA) is a process undertaken jointly by research organizations, development agencies, policy makers, and private businesses. It involves identifying, sharing, and adapting good practices in research and development in specific contexts and on specific topics. It is not a case of looking for one right answer, but rather for the combination and recommendation of knowledge from many different actors as they work together to solve key problems. LAs seek to identify leverage points through which a system can be changed.

The LA approach has been applied to a postharvest research project looking into the use of diatomaceous earths as grain protectants (Annex 2, projects 12 and 23), as the team recognized that if the work was to have widespread impact, the institutional context needed to be examined and addressed. The alliance was viewed as a microcosm of the whole postharvest innovation system (see below). The idea was that the project would not only improve the sharing and adoption of existing ideas but also create a framework within which institutional constraints could be identified and creatively addressed, adaptive management be encouraged, and local ownership of emerging solutions thrive (Morris et al. 2006; Mvumi et al. 2008).

The advantages of a LA

Postharvest Innovation Learning Alliance (PHILA) was created to establish better ways for organizations and individuals to work together to promote the uptake of postharvest technologies, including the diatomaceous earths for stored grain protection (Annex 2, Project 12). Case studies addressing relevant postharvest and related issues were commissioned, and information and reports were shared widely among team members. LA is a new approach that provides unique and interesting challenges to its participants. More could have been achieved if the project timeframe were longer. For an alliance to be mature and effective, a one-year formation period and three years of maturity is recommended.

Source: William Rivva (Project Coordinator, Ministry of Agriculture Food Security and Cooperatives, Tanzania).

households, widows or widowers, and elderly relatives looking after grandchildren. Rapid population growth in many SSA countries means that youth now make up the majority of most of the population. Therefore, any assessment of opportunities for PHL reduction along the chain should include gender and diversity considerations. For example, the introduction of postharvest technologies and practices may, if men or women have little understanding of the requirements of the next stage of the chain, unbalance existing gender divisions of labor, potentially resulting in losses in product quality or quantity. Also, labor saved for women may often be more valuable than labor saved for men because women have a higher propensity to invest saved time in wider family benefits such as child care or enterprise that benefits household welfare. Overall, the research into the gender and diversity dimensions of PHL reduction is limited, although a number of interesting case studies, good practices, and lessons learned are described in the Gender in Agriculture Sourcebook.

This assessment should consider that gender roles are not static; change is taking place in response to many drivers, with numerous diverse outcomes for different people in the community. Some recent postharvest projects are reported to have had positive benefits for women. For example, when mechanization is introduced, men often tend to take over traditionally female roles, which can have both positive and negative outcomes for women and different wealth groups. Rural hammer mills, while typically operated by and employing men, have provided women with a way of saving hours of manually pounding grains into flour. This enables them to invest that time in other productive ways that benefit the household. There is a need to improve the research base of gender and diversity of PHL reduction and ensure that gender- and diversity-sensitive data is collected, analyzed, and used to inform decision making at all levels. A study by Gunther and Zimbrich (1998) provides suggestions for questions that might be asked to help understand and work positively with gender orientation within the postharvest sector. Specific criteria identified for selection of appropriate technologies that are culturally acceptable for women include portable or easily dismantled implements; multi-purpose implements, such as those with exchangeable accessories for processing; and those with minimal consumption of resources.

5. LESSONS LEARNED AND THE WAY FORWARD

Until recently, in the wake of higher food prices and a resurgence of concern about the performance of the agriculture sector in Africa, PHL reduction in grains has been a low priority for the donor community. It is clear, given renewed interest in African agricultural prospects, uncertainty fueled by climate change, and the future likelihood for grain prices to remain 10–20 percent above historical levels, that investments in PHL have become relevant. Effective postharvest management can contribute to conserve scarce resources (labor, water, land, fertilizer, pesticides, etc.), while minimizing the need to produce more food to cover the losses caused by lack of appropriate PHL-reduction technologies and strategies. Loss reduction is not just a matter of promoting technologies and practices, which are increasingly available in Africa as shown in chapters 3 and 4, but must also be considered within a broader context, including the range of incentives, socioeconomic aspects, policies, and business practices.

There are a wide range of technologies and practices available that, if adopted, would enable smallholders and larger producers to improve the quality and quantity of grains during postharvest handling and storage. These include better postharvest grain management, better pest management, enhanced storage structures, and enabling policy and institutional arrangements for grain marketing. The choice of technologies and practices depends on circumstances such as the scale of production, crop type, and prevailing climatic conditions. Success stories, however, are mostly related to technologies transferred from Asia to Africa in the context of labor constraints and higher rural wages. Examples of these technologies include small-scale rice dryers, rice threshers, and new bagging techniques. Successful interventions for more traditional grains such as maize, sorghum, and millet are more difficult to find. However, those identified (such as improved sorghum milling technology in Botswana) have been linked to strong government support, financial incentives to early adopters, and an enabling environment that favors support for infant industries. Some of the identified reasons leading to failure to adopt a technology relate to

non-financially sustainable investments; misidentification of the key constraints, such as focusing on enhancing storage while the economic incentives are missing; lack of cultural acceptability of the approach or technology (e.g., introduction of silos where local populations prefer to keep stocks in their homes); and assumptions that facilitating change can occur over a short period of time, such as a 3-year project.

Postharvest technology adoption has been slow in Africa, particularly for harvesting, drying, and storage technologies that have most commonly been a target for PHL-reduction interventions, perhaps because of the low opportunity cost of labor. Technologies that have taken off in Asia, such as small-scale rice-drying technology and the introduction of pedal threshers and rice mills, may become more interesting in Africa as migration, aging farming populations, and high rates of HIV/AIDS infection reduce available labor and raise wages. In this chapter, key lessons that have emerged from past efforts to reduce PHL are presented, defining the framework of future intervention that appears to be supported by past experience. The key elements of that framework include the following:

- *The impact and success of any postharvest operations and PHL-reduction interventions are influenced by social and cultural norms.* Consequently, planning and implementing of interventions need to be undertaken in a way that takes account of both gender and diversity. In Africa, women play a significant role in postharvest handling, processing, marketing, and household food security. However, there has been limited research into the gender and diversity dimensions of postharvest loss reduction. Interventions that reduce drudgery for women (e.g., the introduction of hammer mills and investments in dehulling equipment for processing sorghum flour in Botswana), offering women more time to pursue productive activities and increasing their ability to care for their children, will reap greater developmental benefits. In some cases, however, adoption of processing equipment removes manual employment

opportunities for women, particularly poorer women. Consequently, it is critical that a gender and diversity lens be used when reflecting on the merits of the interventions and approaches needed.

- *Technology adoption and impact may also differ, depending on the economic and social characteristics of the target groups and on the objectives of interventions.* A reduction in PHL has the potential to address two key developmental objectives: increasing incomes and enhancing food security. The two objectives are not necessarily mutually exclusive, but income enhancement is broadly applicable to smallholders who are net-surplus producers, while the food-security objective is of priority for producers who normally have a net deficit or whose incomes are so low as to render them food insecure. Support to both surplus producers and deficit farmers or net consumers merits attention but requires different approaches. Approaches focusing on enhancing food self-sufficiency can consist of specific technology/institutional push interventions targeted at farm operations with some degree of subsidy involved. Exit strategies should be envisioned, but economic sustainability need not be a priority consideration.
- *Support to net-deficit grain producers can reduce their requirements for grain purchases and food aid.* Net-deficit grain producers may be food insecure at certain times of the year, and grain staples that would normally be stored until next harvest may suffer high PHL that threaten the food security of this group during the “hungry period.” Addressing such PHL can ensure that people are not malnourished and can be an alternative to food aid. Activities to limit PHL for this group, who are often the most disadvantaged or vulnerable within communities, may require different interventions than those needed to help net-surplus producers. Interventions targeted at disadvantaged groups can focus on better harvesting, threshing, shelling, and drying techniques or on the introduction of collective storage through village cereal banks. When improvements require capital investments and the covering of recurrent costs, subsidies could be envisioned. Economic sustainability is not the priority; rather, the key issues are identifying socially and culturally acceptable PHL technology packages for the designated communities or households.
- Conversely, when the objective of the intervention is to increase incomes of surplus farmers through links with markets and optimizing sales of agricultural products, interventions should be seen in the context of impacts along the value chain. To ensure sustainability, *interventions for net-surplus producers should not involve subsidies or should include only those that are market driven and carefully tailored to be eventually phased out.* Examples could include financial incentives to early adopters of a technology. Net-surplus producers are willing to adopt new technologies and approaches that will improve grain quality and quantity, but only when they have a clear financial incentive to do so. Adoption may also be supported by the provision of matching grants depicts a framework for different interventions, depending on the target group and development objective, while Table 5.1 shows the expected impact of various PHL interventions by target group.
- *Increasing competition in grains markets and growing product differentiation necessitate that PHL interventions be embedded within the context of value chains and that they leverage their success from building synergies with the private sector.* To ensure that improvements in postharvest systems are sustainable, focus must be placed on systemic interventions that improve the efficiency of the chain as a whole, and postharvest loss reduction strategies must be developed that provide economic incentives to all actors in the chain. Economic incentives are likely to play a very significant part in reducing PHL. Willingness to invest in improved postharvest approaches is fundamentally dependent upon favorable economic returns.
- *The value and impact of an intervention must be analyzed within the context of the entire chain from production (including the inputs such as seeds, fertilizer, etc.) to consumption.* As the value chain involves many different players, it is essential to develop strategies that promote coordination, collaboration, and information flow among all actors in the chain. Increasingly, PHL are symptomatic of the efficiency of a postharvest system, and a key baseline indicator of an intervention could be PHL figures for targeted actors in the value chain.
- *Market-orientated public and donor interventions need to involve the private sector and share costs and risks.* Within value chains, the successful adoption of technologies by smallholders is likely to be dependent upon the adoption of other innovations by private sector players elsewhere in the value chain. A good example of private sector involvement is the provision of improved rice threshing equipment, which is not affordable or easily maintained by farmers. However,

TABLE 5.1. Expected Impact of PHL Interventions on Self-Sufficiency and Incomes

PHL INTERVENTION	IMPACT	FOOD SECURITY VS. INCOME
Better harvesting/threshing/shelling	Reduces labor requirements leading to timely harvesting and processing that reduce physical PHL.	Net-deficit farmers gain from greater food availability and quality, and reduced risk of forced purchase. Surplus farmers may be unable to capture the gains of better quality without market access.
Better drying		Net-deficit farmers gain from greater food availability and quality, and reduced risk of forced purchase. Surplus farmers may be unable to capture the gains of better quality without market access.
Better store hygiene	Grain with less physical deterioration, more and better quality grain available to consume or sell.	Implementation costs very low, both net-deficit and surplus farmers can capture the gains of greater quantity and better quality.
Better on-farm storage		Net-deficit farmers gain from greater food availability and reduced risk of forced purchase. Surplus farmers gain through arbitrage.
Collective storage	Efficiency gains from group investment in more effective storage methods. Grain with less physical deterioration, more and better-quality grain available to consume or to sell.	Net-deficit farmers gain from greater food availability and reduced risk of forced purchase. Surplus farmers gain through arbitrage.
Collective marketing	Efficiency gains from group action to aggregate, move, and sell grain. Improved opportunities to sell grain, improved prices.	Net-deficit farmers unable to participate. Surplus farmers gain through greater market access.
Market information	Grain sold at highest available market price or bought at lowest price. Improved opportunities to gain better livelihoods from the market.	Net-deficit farmers gain when they have to purchase food. Surplus farmers gain at time of sale.
Inventory credit	Financing available at village level to improve livelihoods from grain production, and upgrade to technologies and approaches that reduce PHL.	Net-deficit farmers unable to participate. Surplus farmers gain from greater liquidity.
Warehouse receipts	Increased demand for grain of better quality, creating marketing opportunities for producer group and better livelihoods from grain production.	Net-deficit farmers unable to participate. Surplus farmers gain from increased sales of better quality grain

Source: Authors.

it is in the financial interest of the private sector to assist smallholders in attaining collective access to this technology (Annex 2, Projects 18 and 19). The incentive for the private sector is that a reduction in PHL within the value chain is ultimately an increase in profitability for all chain actors.

There have been a number of innovative marketing arrangements in recent years involving the private sector, all with the potential to benefit smallholders. These include the establishment of WRS; inventory credit schemes; and the formation of national and regional trade associations that provide a range of services to their members, including training in postharvest handling, input supplies, and support to collective marketing. A few private companies are piloting integrated models for grain handling. The model consists of an agribusiness center that provides drying, handling, and storage facilities and is linked to farmer organizations, banks, and other stakeholders such as service providers and input suppliers. Farmers deliver their harvest to the agribusiness

center and the centers process, store, and market the grain. Most of these innovations are in the infant stages of development, and results have been mixed thus far. Nonetheless, the concepts show promise and are aligned with the market-oriented value chain approach that has been recognized as a sustainable model for postharvest development. In this regard, they merit further development and testing.

Another innovative marketing arrangement is the WFP P4P initiative, which aims to re-orientate WFP's procurement process toward local and regional sourcing. In this regard, P4P encourages local farmer groups and agro-industries to supply grains and other agricultural products according to WFP specifications. Farmers' groups face many challenges to meet these standards; nonetheless, the P4P initiative offers an important market opportunity to those farmers and agro-industries that can meet WFP requirements.

Despite the growing influence of the private sector, the *role of the public sector* in promoting the uptake of PHL-reducing

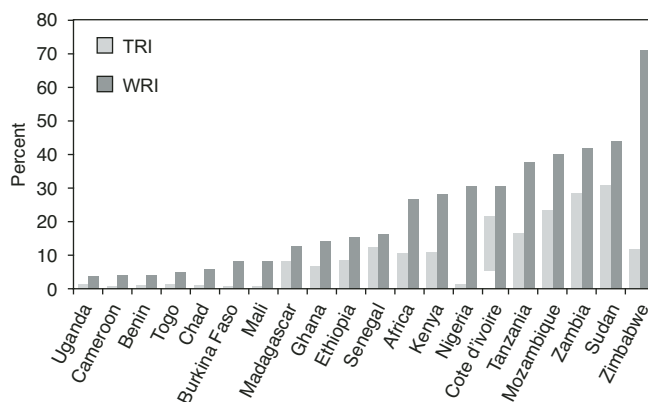
technologies is essential. The private sector's efforts to develop improved postharvest systems need to be underpinned by an enabling environment that encourages private sector investment. It begins with *the improvement of price incentives*, which in most African countries remain quite distorted (Figure 5.1), and *the provision of basic public goods* such as electricity and roads, which would not only make technologies affordable but also shift on-farm activities for PHL reduction to other value chain players. Improved access to markets, for example, would accelerate trade, thereby reducing the need for on-farm grain storage and lowering losses. A predictable price policy would support investments in off-farm storage, which could provide drying and storage services to smallholders at affordable fees and also unleash the underutilized power of the private sector to provide many PHL solutions. Overall, basic critical factors include (among others) predictable policy and price environment, better roads and lower transport costs, better access to electricity to allow local drying and processing, and improved access to rural finance.

An integration of PHL reduction into the *agricultural research and extension* services agenda is necessary to provide technical advice and locally affordable solutions to farmers and private sector players. These services are the key to identifying local issues and opportunities and to helping farmers and the private sector adapt technologies to their needs. The research-extension cycle needs to be reinforced to enable

researchers to propose local solutions and to train farmers and extension officers in innovative postharvest management practices and technologies. Extension officers need to promote these technologies and provide feedback to research. A strong research-extension cycle creates improved opportunities for technology adoption and postharvest improvement.

The weak focus on postharvest issues at the national level is not helped by it being poorly represented in the curricula *for agricultural education and in agricultural policy*. There is the need to increase awareness of the benefits of postharvest improvements at farmer, private sector, and policy level and to build capacity to enable such improvements to be effected. This can be done through (i) including postharvest modules in the curriculum of agricultural colleges; (ii) building farmer and private sector capacity through development of diverse informal as well as formal training and information channels (these could include rural resource centers or village info kiosks, exchange visits, farmer field schools, and more-formal training courses and resource materials); and (iii) harnessing the power of every type of media—radio, newspaper, television, and video. Implementation of postharvest innovations should be guided by learning alliances that enable a broad spectrum of public and private sector stakeholders to jointly identify, share, and adapt good practices and solve key problems.

FIGURE 5.1. Trade and welfare reduction indexes, all covered products, 19 African countries and regional average, 2000–04¹



Source: Croser and Andresen (2010).

¹ Trade reduction index shows the average distortions for imports and exports that restrict trade. These trade distortions affect welfare, defining the welfare reduction index. This figure shows that trade and (correspondingly) welfare distortions remain high in most African countries.

The increased emphasis on competitive, market-oriented systems requires that farmers not only improve their technical skills but also be better organized, act collectively, and acquire stronger group business and marketing skills in order to participate effectively in the value-chain context. Thus, *technical training* must be accompanied by the development of business management and entrepreneurship skills.

Investments in research aimed at the identification of cost-effective drying methods and business models to support their adoption, as well as on promising options to replace chemical insecticides during storage, can yield significant gains in terms of PHL reduction at the farm level. As discussed earlier, proper drying is a critical control point for minimizing the likelihood of high postharvest losses; however, it cannot be achieved with proper management practices alone. Therefore, effective methods need to be in place. Similarly, research has demonstrated that DEs are effective grain storage protectants (as well as being environmentally friendly) and have good potential to substitute for chemical insecticides. Thus, further investment in their research, promotion, and commercialization should be prioritized.

Similarly, *investments in rural infrastructure* and market development create a conducive environment for reducing PHL. Better all-weather feeder roads reduce transport costs and facilitate the delivery of grain (and other agricultural goods) to the market. Affordable electricity promotes the adoption of drying, threshing, and milling equipment and creates additional market outlets through agro-processing. Development of grades and standards that are commercially meaningful, business development services, and market information systems are also conducive to reducing losses and enhancing the overall value of the chain. Improved access to capital can also increase the adoption of PHL-reducing technologies through matching grants, loan guarantees, and equipment leasing schemes. Additionally, it can provide support for the creation and operation of warehouse receipts systems and capitalization of investments funds that underpin small and medium agribusinesses.

The time frame for adoption must be considered early in the planning process if interventions are to be successfully introduced. There are examples of successful adoption of postharvest improvements, such as the storage of maize in metal tanks in Swaziland and the hammer mills that have been adopted across Africa. In these locations, there are marginal but apparently certain returns on investment, and very little external assistance was required to promote adoption. In other cases, however, adoption needs to be fostered and facilitated, and the time required to achieve this should be a key element in the formulation of the project. Assisting communities to adopt new measures (such as technologies that have been successfully adopted in Asia) requires a careful socioeconomic appraisal to ensure that the interventions are needed and acceptable. These innovations should also be economically sustainable, and if subsidies are provided, there needs to be a well-defined exit strategy supported by increased value moving down the value chain. Often, the creation of more responsive institutional arrangements is necessary to mobilize these innovations, and LAs (as discussed in Chapter 3) are an effective approach for taking this forward.

Monitoring and evaluation should feature more prominently in projects. With a few exceptions, the postharvest grain interventions reviewed have not had elaborate baseline surveys, impact indicators, or ex-post evaluations. This paucity of impact assessment and baseline data makes comparison of interventions impossible. By and large, research on PHL has not made links between losses and household poverty or vulnerability. Future PHL projects, therefore, should place much more emphasis on defining these causative links at the

outset and then properly measuring them ex-post so that it is clear where the real impact lies.

New institutional arrangements (national and international) can support and coordinate efforts to reduce PHL. In recent years, the expertise in the community concerned with development in the postharvest sector has eroded, and there is no longer clear leadership or a champion. This is despite the fact that many national and international organizations devote at least some of their resources to activity in this sector. At the international level, there is currently no recognized coordinating mechanism or community of practice for the development of the grains postharvest sector. International and national expertise needs to be focused on encouraging national-level analysts to think of PHL as a key indicator of the efficiency of postharvest systems. The creation of a visible international “structure” is an essential contribution to reversing the trend of decline in postharvest expertise and raising activity within the sector. The new structure needs to connect those groups currently engaged in postharvest activities, be representative of the whole grains postharvest system, and be tasked with pushing developments into use—not just perpetuating individual postharvest interests. These practitioners would come from the NGO and private sector backed by the resources of national and international institutions with capabilities in the sector. The grouping could be built around the existing APhLIS network that is currently restricted to East and Southern Africa (but with planned expansion to include all of SSA).

Understanding of the magnitude of the problem can lead to opportunities to leverage food security and poverty outcomes from PHL reduction strategies. The APhLIS database could be expanded to become an archive of postharvest projects and studies and the counterpart to the FAO INPhO system that provides information on postharvest technologies for all crops, but not data on specific projects. This approach would go a long way toward preserving the institutional memory on postharvest interventions for grain value chains. It could also possibly serve as the foundation of a regional LA to build bridges between the research and development community. However, beyond this repository function, there are other critical steps to make the PHL data more relevant and useful. These steps include a collective effort to generate consensus on methodological aspects of postharvest loss estimation; to strengthen the quality and accuracy of the data collected by APhLIS; and the definition of indicators related to grain quality, safety, and economic value to complement physical estimations of PHL.

REFERENCES

- Adamo, A. 2001. *Participatory agricultural research processes in eastern and central Ethiopia: using farmers social networks as entry points*. Cali, Colombia: CIAT Occasional Publications Series No. 33. CIAT.
- Aker, J. C. 2008. "Towards measuring the impact of the World Food Programme's Purchase for Progress Initiative." Essay. 8 pp. Centre for Global Development.
- Alston, J. M., G. W. Norton, and P. G. Pardey. 1995. *Science under scarcity: Principles and practice for agricultural research evaluation and priority setting*. Cornell University Press.
- Arnold, M. 1996. "Harvest and postharvest problems in agriculture, forestry, and fisheries—the CGIAR contribution to research." Document No. SDR/TAC: IAR/96/5.
- Azu, J. 2010. Opportunity Industrialization Centre, Tamale, Ghana. Personal communication, January 2010.
- BBC World Service Trust. 2006. African Media Development Initiative. Research Summary Report, p. 142. http://downloads.bbc.co.uk/worldservice/trust/pdf/AMDI/AMDI_summary_Report.pdf
- Benhalima, H., M. O. Chaudhry, K. A. Mills, and N. R. Price. 2004. "Phosphine resistance in stored-product insects collected from various grain storage facilities in Morocco." *Journal of Stored Products Research* 40(3): 241–49.
- Benin, S., E. Nkonya, G. Okecho, J. Pender, S. Nahdy, S. Mugarura, E. Kato, and G. Kayoby. 2007. "Assessing the impact of the National Agricultural Advisory Services (NAADS) in the Uganda rural livelihoods." IFPRI Discussion Paper 00724, p. 92.
- Bennett, B. 2010. A Thematic Evaluation of UNIDO activities in the area of Standards, Testing, Metrology, and Quality Management (SMTQ). Vienna: UNIDOBentley, J. W., O. Barea, S. Priou, H. Equisse, and G. Thiele. 2007. "Comparing farmer field schools, community workshops, and radio: Teaching Bolivian farmers about bacterial wilt of potato." *Journal of International Agricultural and Extension Education*, 14(3): 45–61.
- Berg, E., and L. Kent. 1991. *The Economics of Cereal banks in the Sahel*. Bethesda, MD: Development Associates Inc.
- Best, R., G. Henry, and M. V. Gottret. 1994. "El impacto de la industria de la yuca seca en la costa atlántica de Colombia." *El Desarrollo Rural en América Latina Hacia el Siglo XXI, Memorias del Seminario—Taller Internacional*. Pontificia Universidad Javeriana, Bogotá.
- Bhattamishra, R. 2008. *Cereal banks: An institutional and impact analysis*. PhD dissertation. Ithaca, NY: Cornell University.
- Bhattamishra, R., and C. B. Barrett. 2008. "Community-Based Risk Management Arrangements: An Overview and Implications for Social Fund Program Design." Social Sciences Research Network, Working Paper Series <http://ssrn.com/abstract=1141878> (accessed December 17, 2009).
- Boardman, A. E., D. H. Greenberg, A. R. Vining, and D. L. Weimer. 2006. *Cost-benefit analysis: Concepts and practice*. Upper Saddle River, NJ: Prentice Hall, 187–205.
- Boko, M., I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman-Elasha, R. Tabo, and P. Yanda. 2007. "Africa. Climate Change 2007: Impacts, Adaptation and Vulnerability." In *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, eds. M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson. Cambridge, UK: Cambridge University Press, 433–67.
- Borsdorf, R. 2001. "Economic impact of postharvest technologies adopted in Uganda under the postharvest handling and storage project." Technical assistance report submitted to USAID/Uganda, 196.
- Boshoff, W. H. 1979. "On-farm maize drying and storing systems for the humid tropics" FAO/DANIDA, African Rural Storage Centre, International Institute for Tropical Agriculture, Ibadan, Nigeria, FAO Technical Report, Rome.
- Boxall, R. A. 2002a. "Storage losses." In *Crop postharvest: Science and technology volume 1 principles and practice*, eds. P. Golob, G. Farrell, and J. E. Orchard. Oxford, UK: Blackwell Sciences Ltd., 143–69.
- . 2002b. "Damage and loss caused by the larger grain borer *Prostephanus truncatus*." *Integrated Pest Management Reviews* 7: 105–21.
- Braun, A. R., J. Jiggins, N. Röling, H. van den Berg, and P. Snijders. 2006. "A global survey and review of farmer field school experiences." Report prepared for ILRI. Endelee, Wageningen, The Netherlands.
- Chambers, R., R. A. Pacey, and L. Thrupp. 1987. *Farmer First: Farmer Innovation and Agricultural Research*. London: Intermediate Technology Publications.
- Chapman, R., R. Blench, G. Kranjac-Berisaljevic, and A. B. T. Zakariah. 2003. "Rural radio in agricultural extension: The example of vernacular radio programmes on soil and water conservation in N. Ghana." AgREN Network Paper (No. 127).
- Chavez-Tafur, J. 2009. "Building on success." In "Scaling up and sustaining the gains," *Farming Matters/LEISA Magazine*, 25(4): 6–11.

- Coulter, J. P. 2005. "Making the transition to a market-based grain marketing system." Paper prepared for DFID/World Bank Price Risk Management Workshop, Washington, DC, February 28–March 1, 2005.
- Coulter, J. P. 2007. "Farmer groups enterprises and the marketing of staple food commodities in Africa." Collective Action and Property Rights (CAPRI) Working Paper No. 72. International Food Policy Research Institute (IFPRI), Washington, DC, 23.
- . 2009. "Review of warehouse receipt system and inventory credit initiatives in eastern and southern Africa." A working document for comment commissioned by UNCTAD, under the All ACP Agricultural Commodities Programme (AAACP). UNCTAD 105.
- Coulter, J., Brussel, y M. A. P. Wright. 1995. *Programa postcosecha en centroamericas; evaluation de impacto y de la sostenibilidad*. Informe de consultoria para la Cooperacion Suiza para el Desarrollo, Berna, Suiza. Chatham, Kent: Natural Resources Institute (typewritten), 56.
- Coulter, J. P., and P. Magrath. 1994. "Economics of grain handling and storage in developing countries." In "Grain storage techniques: Evolution and trends in developing countries." *FAO Agricultural Services Bulletin* 109: 1–24.
- Coulter, J., and K. Schneider. 2004. "Feasibility study of postharvest project in Mozambique and Tanzania." For the Swiss Agency for Development and Cooperation (SDC) (typewritten), 94.
- Croser, J., and K. Andersen. 2010. "Agricultural distortions in Sub-Saharan Africa." World Bank Policy Research Working Paper 5344.
- CRS (Catholic Relief Services). 1998. Notes from the workshop on community-level grain storage projects (cereal banks): Why do they rarely work and what are the alternatives? Hotel Alfafifa Dakar, Senegal, January 19–22, 1998.
- Dales, M. J. 1996. "A review of the plant materials used for controlling insect pests of stored products." Natural Resources Institute, Chatham Maritime, Kent ME4 4TB, UK. Bulletin No. 65, p. 84.
- De Lima, C. P. F. 1982. *Strengthening the food conservation and crop storage section (Ministry of Agriculture and Co-operatives, Swaziland)*. Field documents and final technical report, project PFL/SWA/002. Rome: FAO.
- Deka, N., and T. Paris. (undated). "Gender roles, constraints and opportunities in postharvest operations of paddy: A case study in Assam, India." Presentation at Assam Agricultural University, India.
- Diagne, M., M. Demont, and A. Diagne. 2009. "Adoption and impact of an award-winning postharvest technology: the ASI rice thresher in the Senegal river valley." Contributed paper for the International Association of Agricultural Economists, Beijing, China, August 16–22, 2009.
- Dick, K. 1988. *A review of insect infestation of maize in farm storage in Africa with special reference to the ecology and control of Prostophanus truncatus*. Chatham, UK: Overseas Development Natural Resources Institute, Bulletin 18, p. 42.
- Dilts, R. 1998. "Facilitating the emergence of local institutions: reflections from the experience of the community IPM program in Indonesia." Paper presented at the Asian Productivity Organization Meeting on the Role of Institutions in Rural Community, Colombo, September 21–29, 1998.
- Douthwaite, B., N. Beaulieu, M. Lundy, and D. Peters. 2009. "Understanding how participatory approaches foster innovation." *International Journal of Agricultural Sustainability* 7(1): 42–60.
- Earl, S., F. Carden, F. Smutylo. 2001. Outcome Mapping: Building Learning and Reflection into Development Programmes. International Development Research Center (IDRC) Canada, 120. http://www.idrc.ca/en/ev-9330-201-1-DO_TOPIC.html
- Ebeling, W. 1971. "Sorptive dust for pest control." *Annual Review of Entomology* 16: 123–58.
- FAO. 1981. "Food loss prevention in perishable crops." *FAO Agricultural Services Bulletin*.
- . 1994. *African experience in the improvement of postharvest techniques*. Rome: FAO. <http://www.fao.org/docrep/w1544e/W1544E00.htm#Contents>
- . 1996. *Food for consumers: marketing, processing and distribution*. World Food Summit Technical Background. Rome: FAO.
- . 2003. *The one to watch: Radio, new ICTs and interactivity*. Rome: FAO (in collaboration with Freidrich Ebert Stiftung), 122. <ftp://ftp.fao.org/docrep/fao/006/y4721e/y4721e00.pdf>
- . 2006. *Food security and agricultural development in Sub-Saharan Africa—building a case for more public support*. Rome: FAO, 122.
- . 2008. "Household metal silos: Key allies in FAO's fight against hunger." Rome: FAO Technical Report.
- . 2009a. *Framework paper on postharvest loss reduction in Africa*. Rome: UN Food and Agriculture Organization (AGS) (type-written), 56.
- . 2009b. Country reports from the FAO/AfDB in support of the "Framework Paper on Postharvest Loss Reduction in Africa." Rome: Working Papers, UN Food and Agriculture Organization (AGST).
- . 2010. *Examples of south-south cooperation technologies*. Technical Report, FAO Liaison Office Japan, GCP/INT/046/JPN, 232.
- FAO/CFC/CIRAD. 2004. "Projet CFC/IGG-(FIGG/02) Amélioration des Technologies Post-récolte du Fonio." Rapport Final. par Cruz, Jean-François (CIRAD).
- FARA. 2006. Framework for African agricultural productivity (FAAP), June 2006 <http://www.fara-africa.org/files/FAAP%20doc%20version%20June06.doc>
- Farm Radio International. (undated). *Traditional core program: Scripts and voices*. <http://www.farmradio.org/english/partners/scripts-voices.asp>
- Feder, G., R. Murgai, and J. Quizon. 2004a. "Sending farmers back to school: The impact of farmer field schools in Indonesia." *Review of Agricultural Economics* 26: 45–62.
- . 2004b. "The acquisition and diffusion of knowledge: The case of pest management training in farmer field schools, Indonesia." *Journal of Agricultural Economics* 55: 221–43.
- Ferris, S., P. Engoru, and E. Kaganzi. 2007. "Making market information services work better for the poor in Uganda." Collective

- Action and Property Rights (CAPRI) Working Paper No. 77. International Food Policy Research Institute (IFPRI), Washington DC, 19.
- Fraslin, J-H. 2004. *CECAM: A cooperative agricultural financial institution providing credit adapted to farmers' demand in Madagascar. Paving the way forward for rural finance, an international conference on best practices*. Case Study. Madison, WI: BASIS—Broadening Access and Strengthening Input Market Systems.
- . 2005. "Une expérience de warrantage à Madagascar. Le crédit Grenier Commun Villageois (GCV) des CECAM (Caisses d'Épargne et de Crédit Mutuels)." Paper presented at the Methodological Capitalization Workshop on Inventory Credit, Niamey, February 2–3, 2005.
- Friendship, C. A. R., and J. A. F. Compton. 1991. "Bag or bulk? A decision-making checklist." Natural Resources Institute, Bulletin No. 45, 19.
- Gallat, S. 2009. UN Food and Agriculture Organization. Personal communication, December 15, 2009.
- Gereffi, G. 2001. "Beyond the producer-driven/buyer-driven dichotomy: The evolution of global value chains in the Internet era." *IDS Bulletin* 32(3): 30–40.
- Gergely, N., B. Guillermain, and L. De Lardemelle. 1990. *Evaluation des banques de céréales au Sahel*. Synthesis report. Rome: FAO.
- Giga, D. P., J. K. O. Ampofo, S. Nahdy, F. Negasi, M. Nahimana, M. Msolla, and S. Nchimbi. 1992. "On-farm storage losses due to bean bruchid and farmers' control strategies." In *A report on a traveling workshop in eastern and southern Africa*. September–October, 1992. Occasional Publications Series No. 8, pp. 35.
- Global Forum for Media Development (GFMD). 2008. "Media matters: Perspectives on advancing governance and development from the Global Forum for Media Development." <http://www.internews.org/pubs/gfmd/mediamatters.pdf>
- Glover, D. 1990. "Contract farming and outgrower schemes in eastern and southern Africa." *Journal of Agricultural Economics* 41(3).
- Gockel, R., K. Hampton, and M. K. Gugerty. 2009. "Storage, transportation, and aggregation of agricultural products for smallholder farmers in Sub-Saharan Africa." Prepared for the Agricultural Policy and Statistics Division of the Bill and Melinda Gates Foundation, August 2009 (typewritten), 36.
- Godtland, E., E. Sadoulet, A. de Janvry, R. Murgai, and O. Ortiz. 2003. "The impact of farmer-field-schools on knowledge and productivity: A study of potato farmers in the Peruvian Andes." Department of Agricultural & Resource Economics CUDARE Working Paper 963. Berkeley, CA: University of California.
- Goetz, S. J. 1990. "Market Reforms, Food Security and the Cash Crop: Food Crop Debate in Southeastern Senegal." PhD thesis, Dept. of Agricultural Economics, Michigan State University.
- Goldman, I. 2005. "Agricultural innovation systems." Presentation made at the UK Department for International Development (DFID) workshop Improving the Productivity of Smallholder Farmers in Southern Africa, Harare, Zimbabwe, September 27–29, 2005.
- Goletti, F. 2003. "Current status and future challenges for the post-harvest sector in developing countries." *Acta Horticulturae* 628: 41–48.
- Goletti, F. and C. Wolff. 1999. "The impact of postharvest research. International Food Policy Research Institute." Paper presented for the meeting on Postharvest Research at the International Centers Week, Washington DC, October 26, 1998.
- Golob, P., N. Marsland, B. Nyambo, K. Mutambuki, A. Moshy, E.C. Kasalile, B. H. M. Tran, L. Birkinshaw, and R. Day. 1999. *Coping strategies adopted by small-scale farmers in Tanzania and Kenya to counteract problems caused by storage pests, particularly the Larger Grain Borer*. Final Technical Report Project R6952. Chatham, UK: Natural Resources Institute.
- Golob, P., and D. J. Webley. 1980. "The use of plants and minerals as traditional protectants of stored products." Report of the Tropical Products Institute.
- Greeley, M. 1982. "Pinpointing postharvest losses." *Ceres* 15(1): 30–37.
- . 1986. "Food technology and employment: the farm-level postharvest system in developing countries." *Journal of Agricultural Economics*, 37(3): 333–48.
- . 1987. *Postharvest losses, technology and employment: The case of rice in Bangladesh*. Boulder, CO: Westview Press, 345.
- . 1991. "Postharvest technologies: Implications for food policy analysis." EDI Development Policy Case Series, World Bank.
- Grolleaud, M. 1997. *Post-harvest losses: Discovering the full story*. Rome: UN Food and Agriculture Organization, 34 (<http://www.fao.org/docrep/004/ac301e/AC301e04.htm#3.2.1%20Rice>).
- Gummert, M. 2010. International Rice Research Institute. Personal communication, January 2010.
- Gunther, D., and E. Zimbrich. 1998. *Gender orientation in the postharvest sector: Pointers for identifying gender-specific aspects in the postharvest sector*. Germany: GTZ. <http://www.fao.org/inpho/content/documents/vlibrary/gtzhtml/x0285e/x0285e00.htm>.
- Haile, A. 2006. "On-farm studies on sorghum and chickpea in Eritrea." *African Journal of Biotechnology* 5(17): 1537–44.
- Hall, A. 2009. "Challenges to Strengthening Agricultural Innovation Systems: Where do we go from here?" In Ian Scoones and John Thompson (eds.), *Farmer first revisited: Innovation for agricultural research and development*. UK: Practical Action Publishing Ltd., 30–38.
- Hall, A., V. R. Sulaiman, N. Clark, and B. Yoganand. 2005. "Chapter 11: Innovation systems perspective: From measuring impact to learning institutional lessons." In *participatory research and development for sustainable agriculture and natural resource management: A sourcebook. Volume 1: Understanding participatory research and development*, eds. J. Gonsalves, T. Becker, A. Braun, D. Campilan, H. de Chavez, E. Fajber, M. Kapiriri, J. Rivaca-Caminade, and R. Vernooy. http://www.idrc.ca/pan/ev-85054-201-1-DO_TOPIC.html
- Hall, A., V. R. Sulaiman, B. Yoganand, and N. Clark. 2003. "Postharvest innovation systems in South Asia: Key features and implications for capacity development." In *Postharvest innovations in innovation: Reflections on partnerships and learning*, eds. A. Hall, B. Yoganand, V. R. Sulaiman, and N. G. Clark, 78–93. Crop

- Post-Harvest Programme (CPHP), South Asia, c/o International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India: Crop Postharvest Programme South Asia.
- Hanbly Odame, H. 2009. "Linking media with rural communities." Presentation made at the Brussels Rural Development Briefings Session n°14 on ACP Agricultural and Rural Development: Why Media Matters. October 12, 2009.
- Hardie, J. D. M. 1982. *Sorghum milling in Botswana: A development impact case study*. Ontario: Office of Planning and Evaluation, IDRC, Ottawa, Ontario, Canada, 44.
- Henkes, C. 1992. "Investigations into insect population dynamics, damage and losses of stored maize: An approach to IPM in small farms in Tanzania with special reference to *Prostephanus truncatus* (Horn)." GTZ, Pichhüben 4, D-2000: Hamburg, Germany, p. 124.
- Hilbeck, A., and D. A. Andow (eds). 2004. *Environmental risk assessment of genetically modified organisms, Volume 1: A case study of bt maize in Kenya*. Wallingford, UK: CAB International.
- Hodges, R. J., W. R. Dunstan, I. Magazini, and P. Golob. 1983. "An outbreak of *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae) in East Africa." *Protection Ecology* 5: 193–94.
- Holmes, R., and R. Slater. 2007. "Realising gender in agricultural policies: The fight for equality is not over." ODI Opinion Paper 91. http://www.passlivelivelihoods.org.uk/default.asp?project_id=240&nc=4921
- IGC. 2008. *World Grain Statistics 2007*. London: International Grain Council.
- Itano, N. 2005. "Community solutions for Africa's AIDS orphans." South African Institute for International Affairs <http://www.saiia.org.za/archive-eafrica/special-feature-community-solutions-for-africas-aids-orphans.html> (accessed on December 17, 2009).
- Jayne, T. S., B. Zulu, and M. Beaver. 2001. "Smallholder household maize production and marketing behavior in Zambia: Implications for policy." Food Security Research Project-Zambia Number 20.
- Kanampiu, F. 2009. CIMMYT. Personal communication, 13 Dec. 2009.
- Kaseke, E. 2006. "The revival of Zundera Mambo in Zimbabwe." *VOSESA Focus* 2(1): April. http://www.vosesa.org.za/focus/vol1_no4/index.html?article_3.html~content (accessed on December 17, 2009).
- Katz, H. 1991. "Desiccants: Dry as dust means insect's death." *Pest Control Technology* 82: 84.
- Kisangani, E. 2005. "Community cereal banks". Technical Brief. Practical Action. http://practicalaction.org/practicalanswers/product_info.php?cPath=87&products_id=50&osCsid=cm1o07n4jl3ug5c6vjfdligkr5&attrib=1 (accessed on December 17, 2009).
- Kitch, L. W., and D. Giga. 2000. "Practical demonstrations of cowpea storage technologies." In *Postharvest storage technologies for cowpea (Vigna unguiculata) in southern Africa*, eds. L. Kitch and T. Sibanda. Proceedings of a regional workshop, Harare, Zimbabwe, April 12–14, 2000.
- Kitch, L. W., and G. Ntourkam. 1991. "Airtight storage of cowpea in triple plastic bags (triple bagging)." CRSP Technical Bulletin 3. Afronomic Research Institute of Cameroon (IRA), Maroua Research Centre, RSP Cowpea Research Project, p. 11.
- Korunic, Z. 1998. "Diatomaceous earths: a group of natural insecticides." *Journal of Stored Products Research* 34(2/3): 87–97.
- Kumar, H. 2002. "Resistance in maize to the larger grain borer *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae)." *Journal of Stored Products Research* 38(3): 267–80.
- Kutukwa, N., and A. Devereau. 2002. "Maize: Zimbabwe." In *Crop Post Harvest Science and Technology. Volume 2: Case Studies in the Handling and Storage of Durable Commodities*, eds. R. J. Hodges and G. Farrell. Oxford, UK: Blackwell Science Ltd., 42–51.
- Langyintuo, A. 2005. "Functioning of cereal banks and inventory credit programs in West Africa: A trip report." Zimbabwe: CIMMYT. http://www.cimmyt.org/gis/rfseedsafrica/documents/Reports/CBs_and_ICP_in_WestAfrica.pdf (accessed on December 18, 2009).
- Lewis, L., M. Onsongo, H. Njapau, H. Schurz-Rogers, G. Luber, S. Kieszak, J. Nyamongo, L. Backer, A. M. Dahiye, and A. Misore. 2005. "Aflatoxin contamination of commercial maize products during an outbreak of acute aflatoxicosis in Eastern and Central Kenya." *Environmental Health Perspectives* 113: 1763–67.
- Liang, L. 1993. "China's Postharvest Grain Losses and the Means of their Reduction and Elimination." *Jingji dili (Economic Geography)* Vol. 1: 92–96.
- Lubulwa, G. 1995. "The human health benefits of research to reduce the hydrogen cyanide potential in cassava cultivars in Africa: A completed project assessment of ACIAR project PN 9007." Economic Evaluation Unit Working Paper No. 21, ACIAR.
- Lubulwa, A. S. G., and J. S. Davis. 1994a. "Estimating the social costs of the impacts of fungi and aflatoxins in maize and peanuts." In *Stored product protection: Proceedings of the 6th International Working Conference on Stored-product Protection*, eds. E. Highley, E. J. Wright, H. J. Banks, and B. R. Champ., Wallingford, UK: CAB International., 1017–42.
- . 1994b. "Estimating the social costs of the impacts of fungi and aflatoxins." Economic Evaluation Unit Working Paper No. 10, ACIAR.
- Lundy, M. 2006. "Change through shared learning." *LEISA Magazine* 22(3): 18–19.
- Mallet, M., and P. Du Plessis. 2000. "A summary of current knowledge about pearl millet postharvest issues in Namibia." Research Report, CRIAA SA-DC, Windhoek.
- Mancini, F. 2006. *Impact of integrated pest management farmer field schools on health, farming systems, the environment, and livelihoods of cotton growers in Southern India*. Published doctoral dissertation, Wageningen University, the Netherlands.
- Mangan, J., and M. S. Mangan. 1998. "A comparison of two IPM training strategies in China: The importance of concepts of the rice ecosystem for sustainable insect pest management." *Agriculture and Human Values* 15: 209–21.
- McLaughlin, A. 1994. Laboratory trials on desiccant dust insecticides. In *Proceedings of the Sixth International Working Conference on Stored-Product Protection, April 17–23, 1994, Canberra, Australia*, eds. E. Highley, E. J. Wright, H. J. Banks, and B. R. Champ (Eds.). Oxford, UK: CAB International, 638–45.

- Morris, M. J., B. M. Mvumi, W. H. Riwa, and T. E. Stathers. 2005. "Postharvest innovation to improve food security in Tanzania and Zimbabwe: Learning alliance lessons." In *Proceedings of symposium on learning alliances for scaling up innovative approaches in the water and sanitation sector, June 7–9, 2005, Delft, the Netherlands*, eds. S. Smits, C. Fonseca, and J. Pels. Delft: IRC International Water and Sanitation Centre, 99–109. <http://www.irc.nl/page/24792/offset/10>.
- Morris, M., B. M. Mvumi, T. E. Stathers, and W. Riwa. 2006. "Postharvest innovation: Enhancing performance at the interface of supply and utilization." Chatham, UK: Natural Resources Institute. Project Final Report, January 15, 2005–January 31, 2006, R8460 DFID Crop Post Harvest Programme. http://www.nri.org/projects/PHILA/reports/PFR_R8460_AS.doc.
- Morris, M., T. Stathers, B. Mvumi, D. Gasana, W. Riwa, and D. Mathias. 2005. "Post-Harvest Innovation Learning Alliance (PHILA): Review workshop, Tanzania." Report of a workshop organized by the PHILA management team, Plant Health Services (Tanzania), the Natural Resources Institute (UK), and the University of Zimbabwe, November 23–25, 2005, at the Muslim University of Morogoro, Tanzania. <http://www.nri.org/projects/PHILA/reports/RWS-report-Tz-Jan06.pdf>.
- Murdock, L. L., D. Seck, G. Ntougam, L. Kitch, and R. E. Shade. 2003. "Preservation of cowpea grain in Sub-Saharan Africa: Bean/cowpea CRSP contributions." *Field Crops Research* 82: 169–78.
- Murdock, L. L., and R. E. Shade. 1991. "Eradication of cowpea weevil (Coleoptera: Bruchidae) in cowpeas by soar heating." *American Entomologist* 37:228–31.
- Muto, M., and T. Yamano. 2009. "The impact of mobile phone coverage expansion on market participation: Panel data evidence from Uganda." *World Development* 37(12):1887–96.
- Mvumi, B. M., M. Morris, T. Stathers, and W. Riwa. 2008. "Doing things differently: Postharvest Innovation Learning Alliances in Tanzania and Zimbabwe." In *Innovation Africa: Enriching Farmers' Livelihoods. Part III: Policy, Institutional and Market-Led Innovation* (Chapter 12), eds. C. Pascal, P. C. Sanginga, A. Waters-Bayer, S. Kaaria, J. Njuki, and C. Wettasinha. London: Earthscan. <http://www.earthscan.co.uk/?tabid=27831>.
- Mukhwana, E. 2009. "Improving agricultural produce marketing." Nairobi: Sacred Africa. www.sacredafrica.com (accessed on December 18, 2009).
- Mvumi, B. M., T. E. Stathers, V. Kaparadza, F. Mukoyi, P. Masiwa, P. Jowah, and W. Riwa. 2006. "Comparative insecticidal efficacy of five raw African diatomaceous earths against three tropical stored grain Coleopteran pests: *Sitophilus zeamais*, *Tribolium castaneum* and *Rhyzopertha dominica*." In *Proceedings of the ninth international working conference of stored-product protection. October 15–18, 2006, Campinas, Sao Paulo, Brazil*. Bortolini, L. de O. F., M. R. Sartori, M. C. Elias, R. N. C. Guedes, R. G. da Fonseca, and V. M. Scussel (eds.). (2007) *Brazilian Postharvest Association*. Campinas, Brazil: 868–76.
- Negi, G. C. S. 1994. "High yielding vs. traditional crop varieties: A socio-agronomic study in a Himalayan village in India." *Mountain Research and Development* 14(3): 251–54.
- New Agriculturalist*. 2004. "Bridging the rural digital divide." *New Agriculturalist*, 04/3. Focus on Extension. <http://www.new-ag.info/04-3/focuson/focuson6.html>.
- Norman, D. W., F. D. Worman, J. D. Siebert, and E. Modiakgotla. 1995. "The farming system's approach to development and appropriate technology generatio." Rome: FAO.
- Okezie, O. B. 1998. "World food security: The role of postharvest technology." *Food Technology* 52(1): 64–69.
- Ospina P., B. Gottret, M. V. Pachico, and C. E. Leite. 1998. "CIAT's integrated cassava research and development (ICRD) strategy: A case study on adoption and impact in Northeast Brazil." Draft. Mimeo.
- Pasteur, K., and P. Scott-Villiers. 2004. "If relationships matter, how can they be improved? Learning about relationships in development." *Lessons for change in policy and organizations, No 9*. Brighton: Institute of Development Studies. <http://www.livelihoods.org/lessons/Learning/OrgLearn.html>.
- Perz, S. 2003. "Social determinants and land use correlates of agricultural technology adoption in a forest frontier: A case study in the Brazilian Amazon." *Human Ecology* 31(1): 133–63.
- Pontius, J., R. Dilts, and A. Bartlett (eds.). 2002. "Ten years of IPM training in Asia: From farmer field school to community IPM." Bangkok: FAO. <http://www.fao.org/docrep/005/ac834e/ac834e00.HTM>.
- Porter, G., and K. Phillips-Howard. 1997. "Comparing contracts: An evaluation of contract farming schemes in Africa." *World Development* 25(2).
- Qamar, M. K. 2005. "Modernizing national agricultural extension systems: A practical guide for policy makers of developing countries." Research, extension, and training division, FAO. <ftp://ftp.fao.org/docrep/fao/008/a0219e/a0219e00.pdf>.
- Quarles, W. 1992. "Diatomaceous earth for pest control." *IPM Practitioner* 18: 1–10.
- Ramírez, R., W. and Quarry. 2004. "Communication strategies in the age of decentralization and privatization of rural services: Lessons from two African experiences." AgREN Network Paper No. 136.
- Reardon, T. 1992. "Food consumption survey issues and methods for West Africa." Mimeo Michigan State University.
- Reardon, T., J. Dione, A. Adesina, and J. Tefft. 1995. "Rice in West Africa before and after Franc CFA devaluation: Focus on CILSS countries." In *Irrigated Rice in the Sahel: Prospects for Sustainable Development. Proceedings of an International Symposium held at Ndiaye, Senegal. March 27–31, 1995*, eds. K. M. Miezán, M. C. S. Wopereis, M. Dingkuhn, J. Decker, and T. Randolph. Bouake: WARDA.
- Reardon, T., and M. Mercado-Peters. 1993. "Self-financing of rural household cash expenditures in Burkina Faso: The case of net grain buyers." In *Finance and rural development in West Africa: Proceedings of the 12th Rural Economy Seminar*, eds. Cuevas and Benoit-Cattin. Montpellier: CIRAD.
- Resilience Alliance. 2007. *Assessing and Managing Resilience in Social-Ecological Systems: A Practitioner's Workbook* (Version 1.0, June 2007). <http://www.resalliance.org/3871.php>. Rivera,

- W., and G. Alex (eds.). 2004. "National strategy and reform process: Case studies of international initiatives." Agriculture and Rural Development Discussion Paper 12, Extension Reform for Rural Development, World Bank.
- Riverson, J. D. N., and Carapetis. 1991. "Intermediate means of transport in Sub-Saharan Africa: Its potential for improving rural travel and transport." World Bank Technical Paper 161, 25.
- Rogers, E. M. 2003. *Diffusion of Innovations*. 5th Ed. New York: Free Press.
- Roling, N. 2006. "Conceptual and methodological developments in innovation." Proceedings of the Innovation Africa Symposium, Kampala, Uganda, November 21–23, 2006. In *Innovation Africa: Enriching Farmers' Livelihoods*, eds. C. Pascal, P. C. Sanginga, A. Waters-Bayer, S. Kaaria, J. Njuki, and C. Wettasinha. Earthscan: London.
- Roling, N., and E. van de Fliert. 1994. "Transforming extension for sustainable agriculture: the case of integrated pest management in rice in Indonesia." *Agriculture and Human Values* 11(2/3): 96–108.
- Samado E., R. G. Guei R, and S. O. Keya (eds.). 2008. *NERICA the New Rice for Africa—A compendium*. (WARDA)
- Saunders R. M., A. P. Mossman, T. Wasserman, and E. C. Beagle. 1980. "Rice Postharvest Losses in Developing Countries." *USDA Agricultural Reviews and Manuals ARM-W-12*. Oakland, CA: USDA.
- Schmidt, E. 2009. "World vision." Personal communication, December 2009.
- Scoones, I., and J. Thompson (eds.). 1994. *Beyond farmer first: Rural people's knowledge, agricultural research and extension practice*. London: Intermediate Technology Publications.
- Shaxson, L., and J. Bentley. 1991. *Economic factors influencing the choice of pest control technology by small-scale Honduran farmers*. Chatham, UK: Natural Resources Institute.
- Shephard, G. S. 2008. "Risk assessment of aflatoxins in food in Africa." *Food Additives & Contaminants Part A Chemistry, Analysis, Control, Exposure & Risk Assessment [Food Addit. Contam.]*, Vol. 25, no. 10: 1246–1256.
- Shepherd, A. 1991. "A market-oriented approach to postharvest management." AGSM Occasional Paper No. 5. Rome: FAO.
- Singano, C. 2009. "Bvumbwi Research Station, Malawi." Personal communication, December 23, 2009.
- Smil, V. 2003. "Improving efficiency and reducing waste in our food system." *Environmental Sciences* 1(1): 17–26.
- Solleti, S. K., S. Bakshi, J. Purkayastha, S. K. Panda, and L. Sahoo. 2008. "Transgenic cowpea (*Vigna unguiculata*) seeds expressing a bean α -amylase inhibitor 1 confer resistance to storage pests, bruchid beetles." *Plant Cell Reports* 27: 1841–50.
- Stathers, T. E., J. Chigariro, M. Mudiwa, B. M. Mvumi, and P. Golob. 2002a. "Small-scale farmer perceptions of diatomaceous earth products as potential stored grain protectants in Zimbabwe." *Crop Protection* 21(10): 1049–60.
- Stathers, T. E., W. Riwa, B. M. Mvumi, R. Mosha, L. Kitandu, K. Mngara, B. Kaoneka, and M. Morris. 2008. "Do diatomaceous earths have potential as gain protectants for small-holder farmers in sub-Saharan Africa? The case of Tanzania." *Crop Protection* 27(1): 44–70.
- Stathers, T. E. 2008. "Smallholder food security in Sub-Saharan Africa: The case for diatomaceous earth grain protectants." PhD thesis, Natural Resources Institute, University of Greenwich, UK.
- Stathers, T. E., R. I. Lamboll, and B. M. Mvumi. Forthcoming. *Climate change and postharvest agriculture*. Natural Resources Institute, UK.
- Stathers, T. E., M. Morris, W. Riwa, and B. M. Mvumi. 2004. *Farmers' livelihoods: What role for grain protection?* Chatham, UK: Natural Resources Institute. <http://www.research4development.info/PDF/Outputs/R8179farmerslivelihoods.pdf>.
- Stathers, T. E., B. M. Mvumi, and P. Golob. 2002b. "Field assessment of the efficacy and persistence of diatomaceous earths in protecting stored grain on small-scale farms in Zimbabwe." *Crop Protection*, 21(10): 1033–48.
- Stathers, T. E., and W. Riwa. 2005. "Farmer and frontline extension staff exchange visits: Case Study 6 of the Post Harvest Innovation Project." Post-Harvest Innovation Learning Alliance (PHILA) Inception Workshop.
- Stathers, T. E., W. Riwa, B. M. Mvumi, and M. J. Morris. 2005. "Small-scale farmers' utilization of diatomaceous earths during storage." *Project Final Report, June 11, 2002–January 31, 2005, R8179 DFID Crop Post Harvest Programme*. Chatham, UK: Natural Resources Institute. http://www.researchintouse.com/nrk/RIUinfo/outputs/R8179_FTR.pdf.
- Stathers, T. E., T. Sibanda, and J. Chigariro. 2000. "The Zunde scheme, Chikomba district, Zimbabwe." *NRI Research Report*. Chatham, UK: Natural Resources Institute. <http://www.cphp.uk.com/uploads/disseminations/R7034-004.pdf> (accessed on December 17, 2009).
- Tran, B. M. D., P. Golob, and A. Fuseini. 2001. "Storage of cowpea in plastic water tanks." *Technical assistance to TechnoServe, Ghana: NRI Report 2585*. Chatham, UK: Natural Resources Institute (typewritten), 29.
- Tripp, R., M. Wijeratne, and V. H. Piyadasa. 2005. "What should we expect from farmer field schools? A Sri Lanka case study." *World Development* 33(10): 1705–20.
- Tyler, P. S. 1982. "Misconception of Food Losses. The United Nations University Press." *Food and Nutrition Bulletin* 4(2), April. <http://www.unu.edu/Unupress/food/8F042e/8F042E05.htm>.
- University of Ghana. 2008. "Harvest and Post Harvest Baseline Study." Draft report prepared by the Department of Agricultural Economics and Agribusiness, University of Ghana.
- van de Fliert, E. 2000. "Stepping stones and stumbling blocks in capacity development of sweet potato ICM farmer field school facilitators." Paper presented at the UPWARD Conference "Capacity Development for Participatory Research," Beijing, China, September 19–22.
- van den Berg, H., and J. Jiggins. 2007. "Investing in farmers: The impacts of farmer field schools in relation to integrated pest management." *World Development* 35(4): 663–86.

- Wanvoeke, J., E. Zossou, and P. van Mele. 2009. "Moving Pictures: Sharing agricultural practices through video." *Farming Matters/LEISA Magazine: Scaling Up and Sustaining the Gains* 25(4): 28–31. [http://ileia.leisa.info/index.php?url=show-blob-html.tpl&p\[o_id\]=239145&p\[a_id\]=211&p\[a_seq\]=1](http://ileia.leisa.info/index.php?url=show-blob-html.tpl&p[o_id]=239145&p[a_id]=211&p[a_seq]=1).
- Watts, M., P. D. Little, C. Mock, M. Billings, and S. Jaffee. 1988. "Contract farming in Africa: Executive summary." IDA Working Paper No. 87. USAID.
- Williams, J. H. 2008. "Institutional stakeholders in mycotoxin issues: Past, present and future." In *Mycotoxins: Detection Methods, Management, Public Health and Agricultural Trade*, eds. J. F. Leslie, R. Bandyopadhyay, and A. Visconti, 349–58. Wallingford, UK: CAB International.
- Winarto, Y. T. 2004. *Seeds of Knowledge: The Beginning of Integrated Pest Management in Java*. New Haven: Yale Southeast Asia Studies.
- Wolfson, J. L., R. E. Shade, P. E. Mentzer, and L. L. Murdock. 1991. "Efficacy of ash for controlling infestations of *Callosbruchus maculatus* (F.) (Coleoptera: Bruchidae) in stored cowpeas." *Journal of Stored Products Research* 27: 239–43.
- World Bank. 1996. *Sustainable transport: Priorities for policy reform*. Washington, DC: World Bank, 131.
- . 2006. *Enhancing Agricultural Innovation: How to Go Beyond the Strengthening of Research Systems*. Economic and Sector Work. Washington, DC: World Bank, 135.
- . 2008. *Agriculture for Development*. Washington, DC: World Bank, 386.
- World Bank, FAO, and IFAD. 2008. *Gender in Agriculture Sourcebook*. Washington, DC: World Bank, 792.
- World Bank (2009). *Eastern Africa: A Study of the Regional Maize Market and Marketing Costs*. Economic and Sector Work, Report No. 49831-AFR. Washington, DC: World Bank.
- World Bank. 2010. *Designing and Implementing Agricultural Innovation Funds: Lessons from Competitive Research and Matching Grant Projects*. Economic and Sector Work, ARD Report No. 54857-GLB. Washington, DC: World Bank.
- World Development Report. 2009. *Reshaping Economic Geography*. Washington, DC: World Bank, 383.
- Wu, F., and P. Khlangwiset. 2010. "Health Economic Impacts and Cost Effectiveness of Aflatoxin-Reduction Strategies in Africa: Case Studies in Biocontrol and Postharvest Interventions." *Food Additives and Contaminants Part A. Chemical Analysis Control Expo Risk Assessment* 27(4): 496–509.

Annex 1. QUESTIONNAIRE SURVEY RESPONDENTS AND AREAS OF EXPERIENCE

NAME	POSITION	CONTACT DETAILS	RELEVANT AREAS OF EXPERTISE											
			PH Tech	Agr Ext	Agr Eng	Stor Tech	Stor Ent	Socio Anth	Agr Econ	Socio Econ	Policy Pro	Comm	Food aid	Business/ Priv Sec
Ambrose AGONA	Director NARO, previously head of the National Postharvest Research Programme, Uganda	aagona@hotmail.com			X		X							
Abel ATUKASE	Assistant lecturer, Makerere University, Uganda	atukwase@agric.mak.ac.ug												
Stephen BELMAIN	Principal scientist, Natural Resources Institute (NRI)	s.r.belmain@gre.ac.uk		X			X	X				X		
Jonathan COULTER	Freelance consultant (formerly NRI)	jcoulter01@yahoo.com				X				X	X		X	
Ben DADZIE	Senior agronomist/ Postharvest Specialist, ACDI-VOCA	benkdadzie@yahoo.co.uk	X											
Shaun FERRIS	Senior Technical Advisor, Catholic Relief Services (CRS)	sferris@crs.org		X	X	X			X	X	X	X	X	X
Stephanie GALLAT	FAO agro-industry and postharvest officer, AGST	stepanka.gallatova@fao.org			X	X				X				X
Denash GIGA	Formerly prof. crop science, University of Zimbabwe.	dgiga@gatorzw.co.uk		X	X		X	X				X		
Peter GOLOB	Freelance consultant (formerly NRI)	petegolob@aol.com		X			X							
Kirstin HELL	Postharvest technologist CIP (formerly IITA)	k.hell@cgjar.org		X		X	X			X				
Patrick LAMECK	INADES Formation Tanzania. Senior trainer and team animator	pgmlameck@yahoo.co.uk		X	X	X		X			X	X		
Anne MBAABU	AGRA, director, market access program	ambaabu@agra-alliance.org		X	X	X			X	X			X	X
Kimondo MUTAMBUKI	Kenya Agricultural Research Institute/head: Entomology	mutambukikimo@yahoo.com					X							
Brighton MVUMI	Lecturer crop protection, University of Zimbabwe	mvumibm@hotmail.com		X	X	X	X				X			
Paul MWEBASE	Formerly, postharvest and marketing specialist, ACDI-VOCA, Uganda	mp88@gre.ac.uk			X				X					
Clare NARROD	IFPRI; SR research fellow	c.narrodd@cgjar.org							X	X	X			

continued

(Continued)

NAME	POSITION	CONTACT DETAILS	RELEVANT AREAS OF EXPERTISE															
Daniel OBENG OFORI	Deputy-provost of College of Agriculture & Consumer Sciences, Legon, Ghana	dobeng@ug.edu.gh			X		X											
Alain RATNADASS	Entomologist (CIRAD) and principal scientist in IPM (ICRISAT)	ratnadass@cirad.fr					X											
William RIWA	IPM coordinator, Ministry of Agriculture Food Security and Cooperatives, Plant Health Services, Tanzania	william.riwa@kilimo.go.tz wilriwa052@yahoo.com		X		X												
Charles SINGANO	Principal agricultural research scientist, Malawi	chasinga2001@yahoo.co.uk				X	X											

Key: PH Tech = Postharvest Technology; Agr Ext = Agricultural Extension; Agr Eng = Agricultural Engineering; Stor Tech = Storage Technology; Socio Econ = Socioeconomics; Agr Econ = Agricultural Economics; Policy Proc = Policy processes; Comm = Communication; Food Aid = Food aid/relief; Business; Priv sector = Business/Private sector.

Annex 2. POSTHARVEST PROJECT PROFILES

PROJECT NO.	PROJECT TITLE
1	Inventory credit (Ghana)
2	Inventory credit (Niger)
3	Warehouse receipts (Zambia)
4	Warehouse receipts (Uganda)
5	Warehouse receipts (Kenya)
6	Market Information Service (FOODNET)
7	Purchase for Progress (P4P)
8	Food Security Project Title II (ACDI VOCA)
9	Postharvest handling and storage project (PHHS)
10	Improved design of indigenous stores—including minimizing the use of hardwood resources
11	Larger grain borer (LGB) control
12	Diatomaceous earth (DE)
13	Mud silos
14	Metal silos PostCosecha type (in Central America)
15	Metal silos PostCosecha type (in Africa)
16	Plastic stores
17	Commodity storage and loss reduction project (Grainpro cocoons)
18	Irrigated Rice Research Consortium
19	East and Southern Africa rice project
22	Improved cowpea storage (triple bagging)
21	Optimizing the indigenous use of pesticidal plants
22	Improving smallholder farmer market access
23	Postharvest innovation: enhancing performance at the interface of supply and utilization (PHILA)
24	Exploring the scope of cost-effective aflatoxin risk reduction strategies in maize and groundnut value chains to improve market access of the poor in Africa
25	Kenya Maize Development Program
26	NAADS Uganda
27	Improvement of postharvest technologies for fonio

NO. 1

Project title		INVENTORY CREDIT (GHANA)	
Project type	Utilization/marketing	Project description	Outputs
Location	Ghana	Working with farmer groups, with about 16-year track record, to facilitate inventory credit for commodities including maize, groundnut, and cowpea. TechnoServe assisted in the management of the groups, drying, cleaning, and storing the produce and in obtaining inventory credit from financial institutions.	
Project dates	1989–2005		
Value (US\$)	n/a		
		Outcomes and impacts	Future prospects
		Although the farmers' groups participating have benefited from the inventory credit system, the scheme has been problematic because the scale of operation was too small. Farmers typically accumulate about 50 tons. The existing financial institutions have little incentive to operate at this scale, with the result that TechnoServe had to make all the running to keep the system operational. The system was therefore not sustainable without subsidy. For this reason, it was discontinued in 2005.	Although the system is worthwhile, it can only really be implemented if it is accepted that some form of subsidy is necessary. It is considered that a pilot scheme of 5–7 years, where gains made using inventory credit are forced into a credit saving scheme, would stand a much greater chance of success, especially where large-scale replication would compensate for inadequacies of scale.

Source: Nick Railston-Brown, TechnoServe (Ghana), Dr. John Azu Opportunities Industrialization Centres (Tamale, Ghana)

NO. 2

Project title		INVENTORY CREDIT (NIGER)	
Project type	Utilization/marketing	Project description	Outputs
Location	Niger	Since 1999, FAO and other partners have implemented an inventory credit system in Niger. It is an approach in which the smallholders, through their producer organization (POs), store their products until the hungry period and secure loans from microfinancing institutions (MFIs) under a "dual key" control system. The loans enable them to undertake income-generating activities or meet financial and social obligations. Subsequently, they can sell stock or retain it for family consumption during the period before the new harvest, when prices are generally high. The project has also promoted the use of technologies to increase production, especially the administration of fertilizer by a system of microdosing (conservation farming).	The positive development of volumes hides important interregional variations. However, the volume stored within the framework of the system represents a little more than 0.1 percent of the production of grains and legumes plants in Niger. The operation of the direct credit MFIs increased very quickly. In 2008–09, the volume of the loans apparently reached FCFA 593 million, which represents about 5,000 tons of products—especially of groundnuts and millet, but also cowpea, paddy, sorrel, sesame, tiger nuts (in Maradi), dried peppers (in Diffa), and several other dry products.
Project dates	1999–present		
Value (US\$)			
		Outcomes and impacts	Future prospects
		FAO promoted inventory credit with other actors, and this proved popular but fell into decline in 2003–04. There was a problem with the mutual MFIs, which were very weak and dependent on external funding rather than members' savings. The situation was corrected when direct-credit MFIs (supported by international investment funds and commercial loans of the trade banks) took over financing, causing an increase in the volume of activity. As a whole, inventory credit in Niger is a success, leaving actual profits for smallholders, and it is apparently sustainable with a good repayment record. It is simple and controllable technically, making it possible for smallholders to better manage their resources, facilitating the adoption of technologies that increase agricultural productivity. In the southern part of Niger, inventory credit seems to be a more powerful tool than cereal banks in promoting food security during the hungry period. In addition, it appears that inventory credit is a good tool to encourage cooperation between smallholders—although, paradoxically, the main attraction of the approach rests mainly on the fact that the food is stored in the name of the individuals, allowing more direct appropriation of any gains.	In reviewing this progress to date, it was proposed that a 5-year project should be implemented to accelerate the adoption of inventory credit in Niger, with a target of FCFA 3 billion loans annually at the end, that is to say about 5 times current volume. Follow-up should include the following: <ul style="list-style-type: none"> • Initiating a strong push to spread the approach used by the project and help to adapt quickly to realities on the ground. • Informing and training smallholders to help them take full ownership and develop their approaches. • Taking a range of steps in the financial field, covering supervision of MFIs, enhancing their analytical skills, working with effective urban-based mutual MFIs to extend their networks, legal aspects, and regulatory support for collateral management and to investigate the scope for monetary measures in support of WRS. • Arranging to ensure that the stores built by the project go to the groups that will make best use of them. • Improving market information systems for the benefit of the POs by involving financial institutions in the collection, analysis, and use of information.

Source: J. Coulter and S. Mahamadou (2009).

NO. 3

Project title		WAREHOUSE RECEIPTS (ZAMBIA)	
Project type	Utilization/marketing	Project description	Outputs
Location	Zambia	<p>With funding from the Common Fund for Commodities (CFC) and other donors, the NRI assisted a range of Zambian parties (including farmers, bankers, traders, millers, and policy makers) to develop and implement a regulated warehouse receipts system (WRS). The approach involved fostering the development of a national network of privately managed warehouses, which are authorized to issue transferable warehouse receipts, and in which trust is developed through a robust certification and inspection system. The WRS was regulated by a nongovernmental certification and inspection agency—the Zambia Agricultural Commodity Agency (ZACA Ltd.). However, ZACA did not perform well for a variety of reasons, and this led to its closure and the establishment of the Zambian Agricultural Commodity Exchange (ZAMACE) through the intervention of a USAID project called PROFIT (Production, Finance, and Improved Technology) and the private sector. ZAMACE started trading in October 2007.</p>	<p>The initial indications from ZACA were positive, and as of March 2003 there were</p> <ul style="list-style-type: none"> • Three warehouse operators with total storage capacity of 23,000 tons certified to issue ZACA-backed WRS. • Staff of the certified warehouses had been trained and certified as competent in grading and sampling of soybeans, maize, and wheat. • Commercial farmers, millers, and small farmer groups, who were keen to make deposits had at least been identified. • Five financial institutions (including two international commercial banks) had shown a readiness to finance ZACA-backed WRS. • Government had indicated strong support for program and is willing to enact supportive legislation for WRS and to discuss enabling policies. <p>Following pilot-phase success, warehouses under the control of four grain traders and an international inspection company were certified to issue warehouse receipts during the 2004–05 season. Available certified storage space rose from 8,000 to 105,000 tons, and about 66,000 tons of maize were deposited in the certified warehouses. Commercial farmers have predominated among the early adopters of this system, but smallholders were also getting involved, depositing nearly 5,800 tons of grain. However the performance of the system declined thereafter. In 2007 it was replaced by ZAMACE, which has focused on the commercial grain sector so that economies of scale will reduce service costs to enable the participation of smallholders.</p>
Project dates	2003–present		
Value (US\$)			
		Outcomes and impacts	Future prospects
		<p>The initial project under ZACA certified a number of warehouses accessible to various depositors of different sizes, with the minimum size of grain deposit of between 10 and 30 tons, a certification system designed to encourage investment in relatively small-scale rural warehousing services. A low capital threshold was established (US\$ 50,000), with warehouses being able to store up to 10 times their net worth. The warehouse operator must meet solvency criteria, provide a financial performance guarantee, show evidence of professional competence and integrity, and accept frequent, unannounced inspections. Only commodities (maize, wheat, and soya bean) that met prescribed weight and grades were to be receipted. Warehouse operators and their front-line staff (samplers, graders, and weighers) were trained and certified in commodity quality and quantity assurance to facilitate enforcement of commodity standards. Certified warehouse operators either own or lease sheds or silos on commercial terms and are free to charge economic storage rates. WRS financing was on commercial terms and unsubsidized, except that it got USAID credit guarantees, which banks only took up for a minority of lending, did not include “soft” credit lines from government or donors. However, despite these efforts, ZACA apparently failed due to the following issues:</p> <ul style="list-style-type: none"> • Lack of a transparent and volume-driven national, commercial commodity market—no scale. • Limited demand for WHR, for warehouse certification, and no confidence by the financial sector. • Legal underpinnings of WHR never established—no clear enforceability of title. • Project support provided for a heavy focus on smallholder participation while not taking due care of other aspects vital to ZACA’s survival. • Lower-than-anticipated performance. • End of funding in 2006. <p>ZAMACE has a stronger commercial focus and is linked to the Malawi Commodity Exchange and to a regional Internet-based trading platform.</p>	<ul style="list-style-type: none"> • Certain economic factors favor a successful outcome in Zambia. There is significant production by large-scale commercial farmers, and the prior existence of inventory credit facilities under collateral management agreements run by international inspection companies suggests that the underlying economics are favorable to the establishment of a system of transferable warehouse receipts. Relative to its neighbors (Zimbabwe and Malawi), Zambia enjoys relative freedom of trade and movement of currency; and the level of seasonal price variability in the leading crop, maize, is very high. The challenges faced in introducing WRS in Zambia include disabling elements in the policy environment, legal issues, engendering confidence among bankers, scale economies, and ensuring smallholder participation. Governments often resort to ad hoc interventions, which can potentially undermine inventory credit programs, on food-security grounds. This phenomenon hampered two schemes in Ghana during the 1990s. Building stakeholder consensus and policy coherence has emerged as critical to reducing, though not eliminating, ad-hoc interventions. In the case of Zambia, this approach enabled local stakeholders to effectively counter pre-electoral policy reversals and prevent the project from being derailed.

Source: Coulter and Onumah (2002), Onumah (undated), Andrews et al. (2007), Cottan (undated).

NO. 4

Project title		WAREHOUSE RECEIPTS (UGANDA)	
Project type	Utilization/marketing	Project description	Outputs
Location	Uganda	<p>The goal was to create an efficient, effective, and properly regulated WRS, based on a network of licensed commercial warehouses. The WRS is regulated by the Uganda Commodity Exchange and will make the agricultural marketing system more efficient, benefiting both producers and consumers in Uganda. The WRS will overcome a range of constraints including long marketing chains, lack of trade finance, weak bargaining position of producers, lack of adequate market information, a slow and costly bulking process, lack of quality premiums at the farm gate, wide distribution margins, large price risk, PHL, and food shortages. At the same time, the enforcement of commodity grades associated with the WRS will help Ugandan traders access more lucrative international and regional markets, as well as provide further value addition—for instance, grain milling.</p>	<p>At the time of writing, three warehouse operators have been licensed to issue warehouse receipts, and five others are in the pipeline, so the WRS is operating on a small scale but with promises of growth. The growth should have been faster were it not for the high investment requirements for warehouses and the processing equipment. UCE states that deposits to date are only maize and are:</p> <ol style="list-style-type: none"> 1. Agroways—2,209 mt 2. Masindi Growers—500 mt 3. Nyakatonzi Growers—340 mt <p>The other warehouses will start depositing this season. Farmers are being helped to participate through training and through provision of moisture meters so that they can check moisture content before coming to the warehouse—to minimize rejections. The system is accepting maize at either grade 1 or grade 2 (East African standard).</p>
Project dates	April 2006– March 2009		
Value (US\$)	1.3 million		
		Outcomes and impacts	Future prospects
		<p>Maize, coffee, cotton, or beans may be deposited at licensed warehouses provided they meet stated quality grades. The minimum deposit is 10 tons, where the warehouse operators issue transferable WRS for deposits through an electronic system based in South Africa. UCE signed an MOU with Housing Finance Bank to finance warehouse receipts where the receipt issued will be placed as collateral for a loan with the bank. The bank will finance 60 percent of the value of the commodity deposited at a UCE-licensed warehouse</p>	<ul style="list-style-type: none"> • The WRS is nascent and needs more warehouse operators to be certified before the planned improvements in the grain market can be delivered. There are two barriers to increasing the number of operators: the relatively small number of warehouse operators in Uganda and liquidity requirements for licensing. A further issue is the incentive for depositors to market their grain through the WRS, given that most existing trade is in grain of low quality and widely variable moisture content. This has been boosted since the UN WFP has adopted more flexible procurement modalities through its Purchase for Progress (P4P) project. WFP will now purchase warehouse receipts, and this has the advantage of enabling them to buy from stock at a predetermine quality. However, WFP would only ever be expected to “prime the pump”; the ultimate aim should be to encourage regional grain traders to purchase the Uganda maize surplus.

Source: Mr. Valerie Alia, UCE chief warehouse examiner.

NO. 5

Project title		WAREHOUSE RECEIPTS (KENYA)	
Project type	Utilization/marketing	Project description	Outputs
Location	Kenya	<p>A WRS was launched in April 2008. It was supported by the Financial Sector Deepening Trust, the USAID Kenya Maize Development Program (KMMP), and Regional Agricultural Trade Expansion Support (RATES). The scheme is regulated by the EAGC, which certifies warehouses on the basis of compliance with regulatory conditions and of reports by inspection companies. Although many banks were reluctant to provide credit based on grain as collateral, Equity Bank developed a special financial product to serve this scheme.</p>	<p>At the time of launch (first half of 2008) the warehouse received 1,000 tons of maize from 10 individual farmers and was encouraging smallholders to form groups and submit their harvest in bulk. Six of the ten farmers applied and received loans from Equity Bank (totaling about US\$130,000), using the warehouse receipts as collateral. In the past two seasons, the combination of low yields and favorable weather encouraged sun-drying of maize and storage in houses so that farmers could bargain for higher producer prices from the government. To appease farmers, the government instituted price controls, increasing the price of 90 kg of maize from Sh1,300 to a high of Sh2,300, which made the WRS offer unattractive.</p>
Project dates			
Value (US\$)			
		Outcomes and impacts	Future prospects
		<p>The first storage facility EAGC certified in April 2008 was the wheat silo complex at Nakuru, operated by Lesiolo Grain Handlers, under lease from the National Grains and Produce Board (NCPB). The WRS was successfully piloted in that year, with Equity Bank as the financial intermediary but on a limited scale. Since then, implementation seems to have slowed as a result of difficulties in the policy area, although the EAGC Web site indicates that two further warehouses have been licensed. Farmers can deposit maize at the licensed warehouses during the harvest period between the months of December to March in exchange for a warehouse receipt. Farmers may then use receipts as collateral for loans, after which they can sell their stored maize at an increased margin in the months of May to August, when prices are expected to have risen. To date, EAGC has approved only maize as the acceptable commodity, and the minimum deposit is 100 tons.</p>	<p>WRS operation has been hampered by government price intervention. The government's intention to restructure both the National Grains and Produce Board (NCPB) and the grain trading system may give an opportunity to expand the WRS, especially to Eldoret, Kitale, and the South Rift regions. Lack of warehousing facilities may present difficulties, although since launch, Lesiolo Grain Handlers has been joined by Export Trading with warehouses in Eldoret and Kitale.</p>

Source: <http://eastafrika.usaid.gov/en/Article.1159.aspx>.

NO. 6

Project title		MARKET INFORMATION SERVICE (FOODNET)	
Project type	Utilization/marketing	Project description	Outputs
Location	Uganda	<p>FOODNET was launched in 1998 as an Association for Strengthening Agricultural Research in East and Central Africa (ASARECA) postharvest and market research network for East and Central Africa implemented by IITA and was the first noncommodity regional research network, with a steering committee that was comprised of researchers, extension, NGOs, universities, and the private sector. FOODNET headed a campaign to introduce demand-led strategies into the regional research agenda, such that products and services would match producer and processor needs. The team worked in a value-chain approach, which included (i) market studies, (ii) agro-enterprise development, (iii) business development support, and (iv) processing, all of which aim to facilitate linking poor agricultural producers to markets. In addition to this work, the FOODNET team also implemented and collaborated on, many postharvest and marketing information projects funded outside the main ASARECA framework by a consortia of donors including, DFID, World Bank, EU, ARD, USAID (ACDI-VOCA), GOU (NAADS, MAAIF), CTA, and RELMA NRI. FOODNET worked with both public and private partners.</p> <p>The main investment grant supported by USAID, was finalized in 2004, and yet part of the staff continue to implement Uganda's Livestock Market Services (LIMIS), supported by Ministry of Agriculture Animal Industry and Fisheries(MAAIF), while also collaborating with FarmGain Africa Ltd. to disseminate crop price information.</p>	<p>FOODNET led a series of competitive grant programs and commissioned studies along the value-chain approach. This included projects based on (i) market studies, (ii) Agro-enterprise development, (iii) value added via postharvest processing, (iv) BDS development, (v) policy analysis, and (vi) capacity building. Projects financed and training provided can be accessed via http://www.foodnet.cgiar.org/Projects/projects.htm. This work was complimented by a series of commissioned grants. The two funding mechanisms were used to maintain focus on project objectives, as it was found that competitive grant systems, despite being fairly proscriptive, led to a higher degree of divergent research pathways than anticipated.</p> <p>The areas of project support aimed to focus on five areas, which included (i) market studies,(ii) enterprise development, (iii) product research, (iv) business development services, (v) policy studies, and (vi) impact studies on previous postproduction research.</p> <ol style="list-style-type: none"> 1. Results from FOODNET projects were published on the Web site and used by the ASARECA commodity networks. 2. FOODNET built up strong networks through PhAction and developed a close working relationship with the CIAT agro-enterprise project. 3. Agro-enterprise LA training programs were developed for leading NGOs and national research programs. The guide from this work was published at: http://webapp.ciat.cgiar.org/africa/agroenterprises.htm, and 4. FOODNET developed a number of market information services at the local, national, and regional levels. <p>FOODNET developed a network of cassava-processing companies that were able to manufacture cassava graters, chippers, and drying equipment. This work was based on a links between East African private companies and researchers in Vietnam and China.</p>
Project dates	1998–2004		
Value (US\$)	\$2,700,000		
		Outcomes and impacts	Future prospects
		<p>In general terms, the project had a considerable impact on other networks, in terms of them having to start their own processes of market analysis and market justification for their investment portfolio. The FOODNET team was also asked to publish work on major economic trends affecting the region such as "globalization." Several national agricultural programs asked for formal training in market analysis for their socioeconomic teams, and the idea of value-chain approaches became a more common part of the research lexicon.</p> <p>The FOODNET project gravitated toward a number of key value chains that were of importance in the region. This led to seven regional market studies being undertaken and published; these included studies on maize, beans, banana, sesame, rice, cassava, and sweet potato. Since that time, value-chain approaches have become important to most agricultural projects' R&D. The FOODNET team led approaches for multisector governance through a steering committee that included research, extension, private sector, NGOs, and universities. Links with research agencies outside of the region also led to ASARECA being engaged in groups such as PhAction. Training of NGOs was undertaken over the following six years, and the agro-enterprise learning approach and impact of the agro-enterprises was published by Catholic Relief Services (CRS) in 2009, see publications library within the CRS PQSD agriculture section. http://www.crsprogramquality.org/category/agriculture-and-environment/</p>	<p>Although the project was officially closed in 2004. Many of the outcomes from the project continued to develop.</p> <ol style="list-style-type: none"> 1. Agro-enterprise training with international NGOs continues to expand, CRS have included more than 50-country programs in this work, and a cohort of consultants continues to use the agro-enterprise guides to expand the approach. 2. Market information services are working on many of the second-generation MIS ideas that were being developed. 3. Cassava processing has potential in East and Southern Africa, and equipment for projects such as the BMG Foundation-funded CAVA project could draw upon the private sector capacity to supply small enterprise manuals and power processing equipment. 4. There remains a large gap in the ability of national research and extension services to provide marketing support. This will at some point in time need to be addressed if these services are to provide relevant support to the farming communities. Projects with the market-led approach led by FOODNET, would be well placed to provide public sector agencies with this type of training and to link new R&D products more effectively into value chain options.

Source: IITA Project 9 Improving Postharvest Systems Report; Dr. Shaun Ferris (ex IITA).

NO. 7

Project title		PURCHASE FOR PROGRESS (P4P)	
Project type	Utilization/marketing	Project description	Outputs
Location	Many developing countries	<p>The UN WFP has procured food in developing countries locally and regionally for many years; in 2008, WFP purchased US\$1.1 billion worth of food in 73 developing countries. P4P builds on local procurement by enabling WFP to develop model procurement modalities that would enable smallholders and low-income farmers to supply food to WFP's global operations and to gain more by doing so. P4P will enable WFP to adopt and institutionalize new procurement approaches and at the same time will give farmers the know-how and the tools to be competitive players in the agricultural marketplace. It will also put more cash directly into their pockets in return for their crops. This initiative is funded mainly by the Bill & Melinda Gates Foundation and the Howard G. Buffett Foundation.</p>	<p>In the first year of operation (2008), 42,000 smallholder farmers all over the world have been involved in selling food to WFP through the P4P pilot. In Uganda, WFP has supported the warehouse receipt system (WRS) through which smallholder farmers can deposit their commodities in a certified warehouse in return for a receipt that can be exchanged for cash at a local financial institution. The value of the receipt is, on average, equivalent to 60 percent of the market value of the deposited commodity, and the balance is paid after the commodity is sold, less storage and cleaning costs. In 2008, P4P Uganda purchased 358 tons of maize through the WRS and in 2009 purchased 600 tons. Through the WRS, farmers can access cash at harvest time without having to sell their produce in a rush. The main advantage to the arrangement with WFP is that it can buy from a stock position where quality and availability are assured; this resolves two common reasons for defaults when purchasing directly from farmer organizations: side selling or not meeting WFP specifications. In Mali, P4P partner, Afrique Verte has worked with farmers' and women's organizations to teach them fundamental market skills like quality and packaging standards or the relevance of delivery on time. Africa Verte educates farmers about how the market works to ensure their sustainable integration into the economy. As a result, one of the farmers' organizations involved, Faso Jigi, was able to win a competitive tender to supply 600 tons of grains to WFP. In Zambia, WFP is working with ZAMACE, a recently established public trading platform. WFP has bought 7,700 tons of maize and beans from the exchange, helping it become a robust market outlet that promotes price transparency and provides an alternative market outlet for farmers. Meanwhile, WFP and partners are supporting farmers' organizations that meet the quantity and quality standards required.</p>
Project dates	2008–present		
Value (US\$)	\$50 million		
		Outcomes and impacts	Future prospects
		<p>Through P4P, WFP is shifting a small percentage of its overall procurement focus from the higher levels of the marketing chain (large-scale traders and processors (WFP's traditional point of entry) to the lower levels (farmers' organizations and small- and medium-scale traders) in order to have a more direct impact on smallholder farmer's income and livelihood. In order to achieve this, WFP is:</p> <ul style="list-style-type: none"> • Adjusting procurement practices in order to facilitate FOs and small- and medium-scale traders' participation in WFP tenders. • Piloting new ways of buying—for example, through commodity exchanges (Zambia and Uganda), warehouse receipt systems (Tanzania and Uganda), grain fairs (Mali) or through direct or forward contacts with FOs. • Depending on the country context and the availability of supply-side partners, entry points may be lower, grass-root level associations or higher-level FOs, including unions and federations that are better able to realize economies of scale. 	<p>WFP has the opportunity to adopt methods of procurement that will benefit markets in developing countries. Especially through purchases from warehouse receipt systems that bring discipline to markets through enforcement of quality grades. The establishment of markets that supply quality grain from a stock position to WFP will encourage other buyers to purchase grain surpluses, bringing reliable demand and sustainability to the market.</p>

Source: <http://www.wfp.org/purchase-progress> and P4P Newsletters.

NO. 8

Project title		FOOD SECURITY PROJECT TITLE II (ACDI VOCA)	
Project type	Utilization/ marketing	Project description	Outputs
Location	Uganda	<p>The objective of the fiscal year 2002–06 Title II DAP was to mitigate food insecurity in rural areas of Uganda by enhancing agricultural production, marketing, rural financial services, and increasing nutritional awareness. Target beneficiaries are approximately 20,000 families in “food-insecure” target areas who are organized by local NGO grantees to receive training in health and nutrition, “farming as a business,” improved agricultural practices, and postharvest handling and storage.</p> <p>The project was funded by USAID/Washington and delivered by ACDI/VOCA. It was implemented through grants to local NGOs formerly referred to as “grantees.”</p>	<p>The number of new farmer groups adopting improved postharvest practices is 76–380 percent over the 2005 target of 20 percent. Households adopting improved postharvest practices rose from 33,600 at baseline to 50,334 in 2005 (90 percent of 2005 target of 56,000). More than 200 maize cribs were constructed during the life of the project. The project initiated collective storage and marketing in the districts of Iganga and Kiboga. By the end of the project, three farmer associations sold grain collectively to WFP. Rural market roads have a high impact in terms of opening market access to isolated areas. The program has rehabilitated 490 km of market road through December 2006.</p>
Project dates	2002–2006		
Value (US\$)	\$11,369,692		
Agric-food security	7,281,320		
Roads	2,500,000		
Rural finance	500,000		
Monitoring	796,370		
		<p>One of the main outcomes is the pilot warehouse receipts system that was implemented in Iganga district by NALG. This group marketed over 1500 metric tons of grain to WFP and Kenyan traders quarterly, using the WRS. The group revitalized 10 dilapidated stores formerly belonging to the Uganda cooperative society that collapsed. This was an indirect outcome of the project.</p> <p>The program provided a grant to IITA to cover over 80 percent of the costs of FOODNET, a national market information service in Uganda that collects and disseminates market data for 19 different commodities from 19 different market centers. The information is processed and disseminated through various radio stations, national newspapers, and by e-mail, text messaging, and fax to major trading companies, government departments, agricultural development agencies, famine-early warning agencies, and cell phone owners. Farmers targeted by the Title II program were most likely to receive information by FM radio in the local language. There is consensus that FOODNET provides reliable, up-to-date market information, especially useful for large commercial farmers, transit traders, ministry officials, and regional wholesalers.</p>	<p>ACDI/VOCA is implementing a new phase of the food security project and a postharvest handling and storage technician to provide TA to agricultural grantees. Previously, this type of TA was provided through the IDEA Project. This was to ensure sustainability when the funding was terminated.</p>

Source: ACDI/VOCA Title II DAP 2002–2006 Final Report.

NO. 9

Project title		POSTHARVEST HANDLING AND STORAGE PROJECT (PHHS)	
Project type	Utilization/ marketing	Project description	Outputs
Location	Uganda	<p>The objective of the postharvest handling and storage (PHHS) project was to disseminate improved drying, threshing, cleaning, and storage technologies in the major grain-producing areas of Uganda. The project was funded by USAID and Uganda and was initially planned to be housed at the national postharvest program (Kawanda); however, the project was merged with the IDEA project. The project was implemented by the food and feed grain institute (FFGI), Kansas State University (KSU).</p> <p>For low-value crops, the project targeted grains including maize, rice, wheat, and beans in the major grain-producing districts of Uganda. The project was active in the districts of Kapchorwa, Iganga, Masindi, Lira, Kasese, and Kiboga, where large volumes of maize are produced annually.</p>	<p>By 2001, the project constructed over 50 maize cribs, 30 mechanical maize threshers, and 10 flatbed grain dryers.</p> <p>The project introduced 10 walk-behind tractors to help with plowing and transport. It also oversaw the design, testing, and roll out of three wheat/rice harvesters in Kapchorwa, the only district where wheat is produced in Uganda.</p>
Project dates	1996–2001		
Value (US\$)	\$3 million		
		<p>The project started the manufacture of a range of new postharvest equipment in Uganda, based on permission and design from IRRI. By the end of project, it had helped to establish three local workshops in Uganda to manufacture locally threshers and dryers as well as cleaning and grading equipment. These factories have continued to operate since the end of funding in 2001.</p> <p>JBT Engineering works, Makerere Road, P.O. Box 11091, Kampala. Phone: +256-77-502709.</p> <p>TONT enterprise, Uganda</p> <p>Afritech Uganda</p>	<p>The mandate, equipment, training packages, and personnel of the PHHS project were transferred to the national postharvest program (Kawanda) to continue with the work and ensure sustainability.</p>

Source: Final unpublished report submitted to USAID (Borsdorf 2001).

IITA report

<http://www.betuco.be/manioc/Cassava%20-%20Processing%20equipment%20uganda%20iita.pdf>.

NO. 10

Project title		IMPROVED DESIGN OF INDIGENOUS STORES—INCLUDING MINIMIZING THE USE OF HARDWOOD RESOURCES	
Project type	Harvesting/storage	Project description	Outputs
Location	Zimbabwe	In Zimbabwe, a modified farm store design was developed using PVC pipes filled with concrete to replace traditional vertical timber supports, which totally excluded rodents and termites.	PVC/concrete legs were initially validated by on-station trials with 12 modified and 12 unmodified stores by researchers from the Institute of Agricultural Engineering (Zimbabwe) and NRI (UK). Further, demonstration stores were built elsewhere, and a rapid assessment was made of their appropriateness to farmers' needs. Relevance and affordability were greater in some locations than others. Outputs were validated by on-farm trials in Binga district Zimbabwe in 1996. Subsequently, demonstrations were undertaken in Buhera and Mutoko districts. The areas concerned have semi-arid production systems and smallholder, rain-fed, dry-farming systems. Following the development of this technology, its extension was inhibited by a serious weakening of agricultural support services in Zimbabwe coupled with problems in the supply of PVC pipes. At the time, the project was supported by staff of the Institute of Agricultural Engineering, which provided essential capacity to advise on building issues.
Project dates	1996–1999	The project was undertaken within the Crop Postharvest Program (DFID, UK)	
Value (US\$)			
		Outcomes and impacts	Future prospects
		Zimbabwean smallholder farmers at several locations are using granaries with concrete legs. The technology has not been extended to other countries, but a manual and video are available to facilitate this. Currently, in Zimbabwe those farmers who previously adopted stores with concrete legs in Binga, Buhera, and Mutoko districts have continued using them, as they are durable and would be effective for many years.	It has become harder for smallholder farmers to invest in PVC pipes due to high costs. The logistics of making the pipes available locally in Zimbabwe is problematic, and the business community in the Zambezi Valley no longer stocks the PVC pipe because of low demand. When economic conditions improve, it would be expected that the use of concrete legs in store construction would resume because smallholder farmers, although apparently not desperately short of timber, do know that timber of the right size and species for store building is dwindling. In Zimbabwe, the decline of support from agricultural services of all kinds is a current barrier to any adoption.

Source: Department for International Development (UK) "Crop Postharvest Program" (R6658).

NO. 11

Project title		LARGER GRAIN BORER (LGB) CONTROL	
Project type	Harvesting/storage	Project description	Outputs
Location	East and West Africa	In the 1980s–1990s, several research projects were supported by DFID (UK) to tackle the newly introduced pest of farm-stored maize, LGB (<i>Prostephanus truncatus</i>). On average, this would cause a doubling of grain losses in storage from around 5 percent to as much as 10 percent. Following investigations of monitoring and pest management, control campaigns and projects were implemented.	Programs funded by DFID and others allowed these measures to be introduced into several countries, with huge results. In Tanzania alone, DFID funding of £0.8 million resulted in a reduction in maize losses equivalent to total gross savings of £21.5 million. At last, farmers were able to fight back against LGB. Meanwhile, research into large-scale storage led to the development of a common set of procedures, the Phytoguide, which have been widely introduced in ports and at land borders throughout East Africa. This reinvigorated the grain trade and increased foreign exchange earnings.
Project dates	1982–2000		
Value (US\$)			
		Outcomes and impacts	Future prospects
		A method of monitoring the pest based on its own chemical attractant was developed, as was an insecticide cocktail that would be appropriate for admixture to shelled maize grain. The shelling of maize and admixture of pesticide represented a considerable change of practice by farmers, most of whom would store maize cobs for lengthy periods. Control and awareness campaigns were initiated to encourage good storage practice and the effective use of insecticide treatments. This included good hygiene practice, not treating with insecticide the portion of crop that would be consumed soon after harvest, looking out for the pest and shelling maize when it is found, treating it with the appropriate insecticide, and storing in a secure store. Biological control was also implemented with the release of a specific predator from meso-America— <i>Teretrius nigrescens</i> , into several countries. Although predator numbers grew in the few years after release, they have reached very low levels or disappeared in most locations (Kenya, Tanzania, Malawi). LGB is, however, still a serious but sporadic problem, causing occasional but devastating damage (e.g., Southern Kenya 2003–04).	The lessons learned from the LGB campaigns are that provided with enough incentive (the threat of losing much of their grain), farmers are willing to change their practice given good technical support and access to technologies that will protect their grain. Widespread problems with LGB are not likely in the future, but it is important that those responsible for farmers remain alert and in a position to implement remedies if required.

Source: Evaluation of LGB projects by DTZ Piedad Consulting (1998); Dr R. J. Hodges (2010).

NO. 12

		DIATOMACEOUS EARTH	
Project title			
Project type	Harvesting/ storage	Project description	Outputs
Location	Zimbabwe/ Tanzania	<p>Many smallholder farmers rely on imported organophosphate pesticides to protect stored grain against insect pests. Farmers and various authorities are increasingly questioning the safety and efficacy of these chemicals. Other households, who use traditional materials such as ashes, botanicals, and sand to control storage insect pests, are faced with inconsistent and often poor results. This project explored the efficacy of the inert dusts known as diatomaceous earths (DEs), which occur as deposits that can be mined. DEs are soft whitish powders formed from the fossils of tiny plankton that lived in oceans, rivers, and lakes. After processing—mining, grinding, and drying—these powders can be mixed with grain to kill insect pests. When DEs come into contact with insects, they absorb the wax from the cuticle of the insect, which then loses water, dehydrates, and dies. DEs have extremely low toxicity to mammals and are therefore very safe to mix with food. In industry they are used as filters to help clarify fruit juices, beers, wine, pharmaceuticals, and as fillers in paints, plastics, and coating agents in fertilizers among many other things. DEs are currently registered for use as grain protectants in Australia, Brazil, Canada, Croatia, China, Germany, Indonesia, Japan, Philippines, Saudi Arabia, United Arab Emirates, the United Kingdom, and the United States.</p> <p>The project was undertaken within the Crop Postharvest Program (DFID, UK)</p>	<p>The project established that DEs were efficacious as grain protectants in a range of agro-ecological zones in Zimbabwe and Tanzania; that the technology—both product and process—was readily usable by diverse smallholders in the multiple research locations; and that food stocks were successfully protected for periods of more than eight months. The research tested both imported commercial DEs and a few of the many local deposits of DE found throughout SSA. The efficacy of imported commercial DEs were validated in three AEZs in Zimbabwe (Buhera and Binga districts and Harare), for two consecutive storage seasons (1998–2000), using maize, sorghum, and cowpeas, under on-farm and on-station conditions. The latter included both researcher- and farmer-managed trials. Similar work was conducted in Tanzania, where the LGB (<i>Prostephanus truncatus</i>), a devastating pest of stored grains, is endemic. The Tanzanian work, carried out over three consecutive seasons (2002–2005) and took place in three agri-ecological zones (AEZ) (Dodoma, Manyara, and Shinyanga regions), where different postharvest practices prevailed. These trials included maize, sorghum, and beans. The efficacies of DEs from local deposits were also validated in field trials in Zimbabwe and Tanzania, during the period 2003–2005. DEs protect household grain reserves and extend their storage life. Value might be added if this technology is part of a package of good practice aimed at optimizing and building on benefits throughout the crop cycle and postharvest sequences. Validation of the DE research involved on-farm researcher-managed trials (RMTs) and farmer-managed trials (FMTs) in three different AEZs in both Tanzania and Zimbabwe. The longest studies extended over three successive storage seasons. Farmers, national and local government staff (researchers, plant health specialists, extension and registration authorities), and NGO staff, participated in the implementation and monitoring and evaluation of the RMTs. DEs proved extremely successful in both sets of trials, with the FMT farmers particularly impressed with the quality and quantity of grain safely stored for the duration of the storage season, especially when compared with some traditional practices.</p>
Project dates			
Value (US\$)			
		Outcomes and impacts	Future prospects
		<p>DEs remain as yet unregistered for general use in Tanzania and Zimbabwe. However, as many as 300 farmers in five districts in Tanzania and Zimbabwe have tested the DEs and are very keen—price issues aside—to continue using them. Many other local farmers and extension staff, who have witnessed the success of the trials, are also keen to use DEs, and communities in Kagera region (Tanzania) and Beitbridge region (Zimbabwe) have long been using DEs from local deposits, to treat stored commodities and whitewash their houses, respectively.</p> <p>Dissemination of the project's findings led to DEs being included in research activities in Zambia and Uganda. As they are not officially registered for use in the two research countries, their distribution for general use (i.e., outside research) remains prohibited. Price will influence their eventual usage and rate of spread, but while available commercial pesticides are found wanting by those farmers who can afford them, it seems highly probable that, once legally available, their usage will spread rapidly. This observation is underpinned by the positive response that DEs have generated among the public and voluntary sector extension staff, registration agency staff, and others involved in the trials. The active interest and rapid follow-up by researchers and entrepreneurs in Zambia and Uganda further corroborates this view. Currently, Dorowa Minerals Limited in Zimbabwe has claims over the Zambezi Valley deposit and is mining the local DE on an experimental basis for industrial purposes, and there is keen interest to widen the product base to include grain protectants following the research findings. There is also some evidence that individuals familiar with the research findings have made land claims in those areas where local DE deposits exist in anticipation of future business opportunities (e.g., in Uganda).</p>	<p>Despite acceptance elsewhere in the world, registration of DEs in Tanzania and Zimbabwe for general use remains problematic. In Tanzania, where only existing agro-chemical companies are likely to be able to complete the DE registration process, currently most of the interested companies have financial commitments with the prevailing organo-phosphate-based (OP) pesticides, which remain cheaper to import. While concerns relating to the safety of these OP chemicals are not acted upon, this situation is likely to persist. In Zimbabwe, the registration process initiated in 2002 is still pending because of the economic situation. In Zimbabwe, bulk importation costs of commercial DEs were estimated to be similar to their chemical equivalents, but in Tanzania the estimates (for application at the rate of 0.25 percent w/w for the control of LGB) were estimated to be twice that of importing the active ingredients of synthetic pesticides (e.g., actellic super dust, shumba super dust). However, further work is needed to confirm these various estimates in order to decide whether the price of imported DEs would make them prohibitive for small-scale farmers. The use of locally sourced DEs will probably offer more economically sound (i.e., to the state) and financially viable (i.e., to business and to farmers) options in the longer run; further work is first required to establish and implement safety, extraction, and processing protocols. A preliminary environmental impact assessment of the Zambezi Valley DE deposit revealed concerns that mining activities may degrade the environment of the national park. However, DE deposits are not uncommon in Africa, and others may have less significant environmental impact if mined.</p>

Source: Department for International Development UK, *Crop Postharvest Projects R7034 and R8179*. Dr. T. E. Stathers.

NO. 13

Project title		MUD SILOS	
Project type	Harvesting/ storage	Project description	Outputs
Location	Ghana	<p>This project is a composite of several interrelated efforts to promote the use of mud silos in northern Ghana. Mud silo adoption programs were launched in northern Ghana to offer this structure to smallholder farmers who traditionally do not use it. Local artisans were used to demonstrate the building of mud silos, and this was easily achieved because groups that traditionally construct mud silos lived adjacent to groups that use other store types and were the subject of the extension program. Adoption of mud silos by new users was validated in June–July 2003 in three districts in northern Ghana—Saboba/Cheriponi, East Mamprusi, and Gushiegu/Karaga. The production system—farming system for all districts was the same: semi-arid, smallholder, rain-fed dry.</p>	<p>Mud silos were adopted by over 1,000 farmers in the Gushiegu/Karaga district of northern Ghana; most of those surveyed are currently using them successfully. Mud silos—for the survey sample of 60 farming families—include the following benefits:</p> <ul style="list-style-type: none"> • Reduction in storage losses. Mean losses now about 50 kg maize per year compared with 300 kg in two districts Saboba-Cheriponi and Gushiegu/Karaga. • Improved food security for household. Farmers said they were generating and maintaining larger food surpluses, as evidenced by storage of maize for up to 12 months. • Time-saving for other household assignments. Although mud silos require maintenance, labor inputs are less than with conventional stores. • Reduced exploitation of wood lots. Can avoid travelling long distances to obtain the correct type of wood for the construction of traditional stores. • Annual savings by not buying jute sacks. A small but positive financial incentive. • However, incomes not much better; surplus not sufficient to risk sales of staple crops later in the season to benefit from higher prices.
Project dates			
Value (US\$)			
		Outcomes and impacts	Future prospects
		<p>Mud silos were evaluated by socioeconomic survey and technical studies in northern Ghana. The socioeconomic survey (PRA) examined expectation and demand, and it showed that expectations of the effectiveness of mud silos were similar to the reality of what they provide. In selected villages, the Ministry of Food and Agriculture (MoFA) and partners constructed a mud silos demonstration in six districts of the northern region. By 2000, the positive feedback on the use of mud silos led the Opportunity Industrialization Centre of Tamale (OICT) and MoFA to undertake a large mud silo extension program in two districts with USAID funding. To evaluate the success of program to promote the silo to new users, an 8-day field survey was undertaken in northern Ghana of 60 farmers to examine impact on food and cash security and observe any problems with these new structures.</p>	<p>Further promotion of mud silos is not currently being undertaken but guidelines for achieving better promotion are available from a leaflet on the CPHP Web site:</p> <p>(Andan F. H. (2004) Ensuring better promotion of mud silos in northern Ghana. Leaflet. Ministry of Food and Agriculture, Tamale, Ghana. 2 pp, at http://www.cphp.uk.com/media/default.asp?step=3&sf=2)</p>

Source: Department for International Development (UK) Crop Postharvest Program Project R6502; Dr. John Azu (OICI), Tamale Ghana.

NO. 14		METAL SILOS POSTCOSECHA TYPE (IN CENTRAL AMERICA)	
Project title		Project description	Outputs
Project type			
Location			
Project dates	2008–present		
Value (US\$)			
		Outcomes and impacts	Future prospects
		<p>Metal silos of a range of sizes—0.1 to 3 tons, suitable for smallholders have been promoted by the PostCosecha program in Central America supported by SDC (Swiss Agency for Development Cooperation).</p>	<p>Several technical/sociological evaluations by consultants hired by the SDC, up to 2002, have reported that metal silos in Latin America are very effective as storage structures used by smallholders, and their promotion has proven very successful. Under the SDC project, there have been 266,000 official transfers of metal silos in Latin America, mostly to smallholder farmers. However, it is estimated that the actual number transferred to date is around 6,000,000. The latest evaluation estimated that subsidies represented 40 percent of the effective demand and that this is growing because the governments of the three countries concerned (Honduras, Paraguay, and the Dominican Republic) are planning massive transfer programs of their own. Metal silos have been validated in Latin America in wide-ranging production and farming systems and have been the subject of large-scale extension programs involving donors, government organizations, and NGOs. Success has been achieved by promotion to farmers and their households and simultaneous support to micro-industries meeting demand for the silos. To implement metal silo programs, it is essential to have the materials (sheet metal of appropriate quality) and to train the local artisans to construct them to the required standard.</p>
		<p>Current scale of use in Latin America is relatively large, with perhaps 1.5 units for every 100 head of population, and is set to increase as Honduras, Paraguay, and the Dominican Republic are planning transfer programs. In Swaziland, current use is about 10 units per 100 head and stable, maintained by a strong incentive framework for maize production. When properly sited and used with adequately dried grain, the metal tank shows major pest control advantages over traditional systems of storage. A three-country survey in 1995 of more than 500 farmers, craftsmen, and others showed positive impacts on poor households (direct and indirect) and livelihood impacts related to micro-industries manufacturing the silos. Direct improvements in the grain economy are:</p> <ul style="list-style-type: none"> • More grain (and grain of better quality) available to the family, especially at times of the year when grain is less available. • Drastic reduction in PHL so additional income is achieved as more grain is available for sale, especially in times of elevated prices, or family debts reduced as less grain needs to be purchased when prices are high. • Situation of women improved, noted particularly in the case of Guatemala, as silos and food management rest with women. Silo ownership gives better control of grain management, and because grain is stored shelled and clean, calculations on whether or not there can be sales are more easily made. 	<p>Very high adoption rates have been achieved in Central America, over a period of more than 20 years, by a social-marketing approach that attended to all elements of the marketing mix—product, price, distribution, and promotion. Continued interest by countries in the region adopting the same approach will see further adoption of the technology.</p>

Source: Max Striet (SDC), the PostCosecha Web site, and review reports (especially Coulter et al. 1995).

NO. 15

Project title		METAL SILOS POSTCOSECHA TYPE (IN SELECTED COUNTRIES IN AFRICA)	
Project type	Harvesting/ storage	Project description	Outputs
Location	list	<p>FAO headed a program for the promotion of the SDC design of metal silos in Africa, and they have also been promoted and researched by a current initiative involving CIMMYT and NGOs (World Vision and CRS) in Kenya and Malawi. Many silos were distributed to farmer groups free of charge; they were also promoted through revolving credit funds and payments in grain.</p>	<p>By all accounts, the extension in Africa was not without its problems. In Mozambique, the dissemination failed due to an inadequate capacity for local fabrication. In Malawi, metal silos of 250-kg, 500-kg, 900-kg, and 1.9-ton capacities were made available, but the largest capacity supplied wouldn't fit inside houses, and costs were considered high (MK 17,000–65,000, = US\$120–450). Farmers were given very little training in use and were reliant on extension services to fumigate grain. Consequently, many of the silos that were supplied free of charge were not used. The main reasons for this would appear to be (1) a security issue—farmers want grain to be inside their house, (2) requirement for a fumigation treatment being done by the extension services, and (3) the silos were targeted at the community rather than at the individual. Currently, the farmers' main approach to storage is to have bags in their houses, which they consider cheaper, more convenient, and more secure.</p>
Project dates			
Value (US\$)			
		Outcomes and impacts	Future prospects
		<p>Details of the successful (or otherwise) promotion of silos in countries other than Malawi and Kenya are expected from the CIMMYT study and from a review planned by SDC.</p>	<p>The current tax situation in Tanzania makes purchase of the appropriate quality of sheet metal to construct SDC-style silos very expensive—cost issues have to be addressed. However, the prospects for the extension of metal silos in Africa are good, provided care is taken to ensure that they are promoted to those who would gain by not using sack storage and that suitable effort is taken to address all elements of the marketing mix—product, price, distribution, and promotion, as well as socio-cultural consideration such as individual ownership.</p>

Source: FAO (Stephanie Gallat); Malawi (Bvumbwie RS—Charles Singano); CIMMYT (Dr. F. Kanampiu).

NO. 16

Project title		PLASTIC STORES	
Project type	Harvesting/ storage	Project description	Outputs
Location	Ghana	<p>Plastic water tanks can be adapted as grain stores, and this has been demonstrated for use by cowpea traders in northern Ghana. Several years of testing options for a viable warehousing business model for rural enterprises and of using brick and mortar stores, butyl rubber stores, and plastic tanks have shown the latter to be the best option.</p>	<p>Plastic water tanks were validated at 13 sites in 2001 by traders who stored and fumigated cowpeas in them. This was done in Tamale, northern Ghana, in a semi-arid production system and in smallholder, rain-fed dry-farming.</p>
Project dates			
Value (US\$)			
		Outcomes and impacts	Future prospects
		<p>Plastic tanks had been used by traders, who found them sufficiently hermetic when filled with cowpeas that there were no insect problems, even without fumigation. However, usage has declined, with only a few traders still using them in October 2006. This was because Nestle Ltd. (Ghana), who had been interested in purchasing cowpeas, would not do so because produce quality was below specification.</p>	<p>The initial success of plastic tanks in northern Ghana was based on an opportunity to supply a commercial company in southern Ghana with local produce (cowpeas). The opportunity was identified by an NGO (TechnoServe) and the technology adapted successfully to the traders' benefit. However, the continued and expanded use of the technology was hindered by a failure in the ability of traders to secure cowpeas of sufficient quality from farmers. The lesson in this case is that the needs of each link in a new market chain must be carefully defined and supported until the whole chain is well established.</p>

Source: Tran et al. 2001.

NO. 17		COMMODITY STORAGE AND LOSS REDUCTION PROJECT	
Project title		Project description	Outputs
Project type	Harvesting/ storage		
Location			
Project dates			
Value (US\$)			
		<p>The objective of this World Vision Relief and Development Commodity Storage and Loss Reduction Program was to reduce constraints associated with food aid commodity, seed, and PHL in four countries through the implementation of a pilot project to test the effectiveness of hermetic grain store. The project implementation activities were as follows:</p> <ul style="list-style-type: none"> • Angola: compared warehouses to hermetically sealed silos, tunnels, and Cocoons™ for storage of food aid commodities; one small seed/postharvest test • Mozambique: traditional local storage was compared to hermetically sealed silos, tunnels, and Cocoons™ for storage of postharvest domestic production • Sierra Leone: compared warehouses to hermetically sealed silos, tunnels, and Cocoons™ for storage of food aid commodities • Sudan: compared warehouses to hermetically sealed Cocoons™ and tunnels for storage of locally purchased grain and seed. 	<p>A two-month test showed little difference in performance between Cocoons™ and other warehousing. Differences could often be attributed to error (e.g., improper closure or inaccurate moisture meter calibration). The following was concluded:</p> <p>(1) When used properly, the Cocoons™ performed as described in GrainPro literature and in many instances performed better than traditional alternatives. (2) Optimal results often were compromised due to various constraints:</p> <ul style="list-style-type: none"> • hermetic seal (zipper problems) • rodent damage (in storage, when not full, when high density of rodents) • set-up complexity of large units. <p>(3) After storage in a Cocoon™, there was no difference in seed germination over 60 days of storage. (4) Disadvantages included:</p> <ul style="list-style-type: none"> • not an in/out technology • requirement of exact tonnages • security (value of asset, easy access) • if there is a "problem, it might go undetected. <p>(5) Advantages for use in some situations:</p> <ul style="list-style-type: none"> • smaller Cocoons™ useful for temporary storage in outlying areas/villages (no hermetic advantage) • able to segregate commodities within large warehouse (damaged commodities) • provides longer-term storage if warehousing is scarce.
		<p>Outcomes and impacts</p> <p>It is difficult to compare the cost of a Cocoon™ with local storage because there is no investment cost in local storage structures. Mud, wood, and other required storage materials are available locally. WV/Mozambique therefore attempted to place a money value on the labor required for local construction, but the assigned monetary value is too low for comparison. The Cocoons™ are expected to deliver financial benefits to the farmers. An analysis found that a 5-ton Cocoon™ must have a life span of three years for farmers to break even. This analysis was based only on the initial cost of the Cocoon™ and assumed that farmers would pay cash rather than by credit at a 20 percent interest rate. The opportunity cost of the use of the money is a variable that can affect profitability, and this was not taken into consideration in the analysis.</p> <p>The Cocoons™ pose the following constraints/disadvantages:</p> <ul style="list-style-type: none"> • high investment cost • tying down of capital which could result in financial loss • structural difficulties in closing the Cocoons™ • rodents can penetrate folds in the Cocoon™, thereby destroying the hermetic seal and allowing insects to gain entry into the Cocoons™. 	<p>Future prospects</p> <p>It is believed that Cocoons™ can be a useful technology in Africa, particularly as a means of alleviating labor constraints. It is an environmentally friendly technology and can preserve grain quality to result in increased income for farming households. As the storage period for these studies was short, further research is needed before recommendations can be made to farmers concerning the use of Cocoons™. Further research is needed on the following issues:</p> <ul style="list-style-type: none"> • length of time grain can be stored while still maintaining quality for sale and consumption • resistance to moisture migration • structural difficulties in closing the bags • evaluation of weight loss due to actual insect damage as opposed to reduction in moisture content • appropriate training of farmers • resistance to penetration by rodents.

Source: Commodity Storage and Loss Reduction Project Dissemination Workshop, Port-Au-Prince, Haiti June 29–July 2, 1998; Johannesburg, South Africa, July 27–29, 1998.

NO. 18

Project title		IRRIGATED RICE RESEARCH CONSORTIUM	
Project type	Product quality, harvesting, and storage	Project description	Outputs
Location	Loas, Cambodia, Indonesia, Myanmar, Vietnam	Partnership with the stakeholders from the public and private sector to increase the value of farmers' rice crops through improved crop and postharvest management and market knowledge. Four different but interrelated working groups implement the project: "Postproduction," "Productivity and Sustainability," "Water Saving," and "Labor Productivity." For postproduction, the technologies offered were combine harvesters, dryers, and hermetic storage. Phase I of the project was largely managerial. Phase II: Discussions about including postharvest in the consortium. Initial activities on component technology development and testing. Phase III: Verification of postharvest technologies at farm level in five countries. Phase IV: Developing business models for using PH technologies and facilitation of a multistakeholder platform to embrace the different stakeholders from public and private sectors needed for out scaling. The project is still in Phase III.	Working with an initial basket of technologies developed under other projects, further technologies were added as needs were identified. These included hermetic storage (cocoons and super bags), low-cost moisture meter, methods for milling evaluation and improvement, a milling chart, village market information system, mini-combined harvester, flatbed dryer with rice husk furnace, granary improvements, and balances for weighing paddy sold by farmers.
Project dates	1997–present		
Value (US\$)			
		Outcomes and impacts	Future prospects
		Dryers: Target has been contractors that provide drying services to farmers and the commercial sector (mainly rice millers and a few traders). Six dryers were installed; two in Myanmar at farmers' groups, two in Cambodia were installed at farmers' groups, and two in Vietnam at farmers' cooperatives. Historically, no successful introduction of dryers to individual farmers except the SRR low-cost dryer in Vietnam (US\$100, 1-ton capacity), but this dryer served as an entry point to promote dryers and is now being replaced by larger flatbed dryers for contractors and millers. Combine: Target is larger farmers and harvesting contract service providers. Hermetic storage: Super bags (50 kg) target mainly farmers, entry point is farmers' seeds but also for grains. Second target is rural seed producers, third is larger seed producers. Cocoons (5 t): commercial sector (seed producers, millers) and farmers' groups (cooperatives in Indonesia and Vietnam, farmers' groups in Cambodia). The main target group is farmers, but we also work with the private sector because if the private sector establishes a market for a technology, it also becomes available to farmers. Problem at the moment is the lack of supply chains for the super bags in most countries reaching farmers as end users.	The project has established important preconditions for technology uptake. All technologies: A technology champion pushing the technology, some sort of multistakeholder platform engaging the stakeholders from the public (research, extension, policy) and private (farmers, manufacturers, millers, traders, banks). Dryers: Double-cropping systems with one harvest season in the wet season or other problems that limit sun drying (e.g., lack of pavements and roads, market incentive for better quality, availability of either capital at end users or credit lines)—investment and working capital to buy crop, if not on fee basis—local manufacturing capacity, extension support. The dryer is typically for contractors or millers, so scale of production is not that important (4–8 t in 8 hours), but crop needs to be available for several months of operation per year. Combine harvester: Plausible promise (suitable technology or concept prototype), high harvesting cost, and labor shortage during harvesting. Contractors' machine, mini combine, can harvest very small fields (1.1 m cutting width, 1 ha per day), some technical skills for maintenance and servicing, availability of capital or financing schemes, suitable soil conditions during harvest time for mobility. Super bags and cocoons: Entry point is seeds, so there are problems with traditional seed storage methods (e.g., rapid loss of germination), supply chain for the bags reaching to villages (e.g., through farm input providers), extension (public or private), understanding of seed quality and factors that affect it and that farmers store their own seeds. If used for grain storage, there must be sufficient storage time and problems with traditional storage.

Source: Martin Gummert, IRRI, Philippines.

NO. 19

Project title		EAST AND SOUTHERN AFRICA RICE PROJECT	
Project type	product quality, harvesting and storage	Project description	Outputs
Location	Mozambique, Tanzania, Kenya, Uganda, Rwanda, Burundi, Malawi	Project implemented by IRRI and WARDA, partnership with the stakeholders from the public and private sector to increase the value of farmers' rice crops through improved crop and postharvest management and market knowledge. Demonstrating a range of technologies, already successfully extended by IRRI (project 9) in SE Asia, including two-wheeled tractors, threshers, cleaners, a drum seeder, cone weeder, super bags, and the IRRI moisture meter. The project premise is that delays during harvesting, threshing, and drying cause losses in grain quantity and quality. Losses range from 15 to 50 percent mostly due to poor postharvest management, outdated postharvest technology, and poor and unhygienic storage facilities. Because the crop is hand threshed, farmers prefer to harvest at lower moisture content as this makes threshing easier. This means that the crop is left in the field a month longer than necessary. This results in less grain and poorer grain quality. Farmers also tend to sell their grain at point of harvest; the value of the crop rises 20–30 percent within 2–3 months of harvest, so there is a premium to be gained from better storage.	Several manufacturers have already expressed a strong desire to collaborate with IRRI in manufacturing the equipment locally. One local equipment dealer and manufacturer, said, "This is the opportunity that we have been waiting for, and we want to work with IRRI to manufacture the thresher and the other equipment locally." The IRRI moisture meter and the IRRI super bag have drawn a lot of attention, as they can be used for other crops, especially maize and soybean. Most of the equipment demonstrated will be tested further in a new collaborative village-level rice project in Zambezi Province in central Mozambique. IRRI will work with IIAM, the Tropical Research Institute of Portugal (IICT), and Eduardo Mondlane University of Mozambique (UEM) to develop a model for a sustainable rice business at the village level.
Project dates	2007–present	Outcomes and impacts	Future prospects
Value (US\$)		<p>Approach—the use of equipment must show a strong financial benefit, have local ownership and dealer support, have a local champion, have government support, and provide training for all players. IRRI's experience in Asia suggest that it takes 8–10 years for the mechanization program to develop fully—from initial testing to local ownership and wide-scale adoption. On-farm demonstrations, support for the private sector and local training in the use and maintenance of equipment are already taking place.</p> <p>Hire of machinery contractors in Africa is very high—large tractors US\$70–80 per hectare for one pass; rice millers charge US\$80–100/ton for contract milling. These costs are nearly three times those of their Asian counterparts. However, labor costs are similar: US\$1–2 per day. Imported machinery is also very expensive, a tractor costing US\$2,500 in Thailand and US\$5,000 in Tanzania. In the short term, cooperative ownership appears to be the obvious solution for purchasing equipment, and local credit organizations have already started working with them.</p>	Project is still in relatively early stages.

Source: Mr. Joseph Rickman, representative of the IRRI, East and Southern Africa.

NO. 20

Project title		IMPROVED COWPEA STORAGE (TRIPLE BAGGING)	
Project type	Product quality, harvesting, and storage	Project description	Outputs
Location	West Africa	The Bill & Melinda Gates Foundation is currently funding a large regional West Africa food security project (Purdue Improved Cowpea Storage (PICS), being implemented by World Vision and Purdue University), with assistance from National Agricultural Research Institutes. The project is extending hermetic triple plastic bags of 100 kg capacity, each costing ~US\$1.8, to 12,660 villages throughout Niger, Mali, Chad, Ghana, and Senegal (E. Schmidt, World Vision, per communications in December 2009). In addition to supporting extension and farmer training, they are linking with the bag manufacturers and retailers to enhance long-term access.	In Niger bags have been distributed free of charge to five households in each of >5,000 villages as part of the promotion activities, but other households have been buying the bags. The PICS project is using two inner bags made of 80 micron polyethylene and one outer, more durable bag to help protect against damage. The government of Niger stored 10,000 mt of cowpeas in these hermetic triple plastic bags in 2008–09 for strategic food reserves.
Project dates		Outcomes and impacts	Future prospects
Value (US\$)		The bags have been found to be easily accepted by farmers, providing a very high level of insect control, and they can be used for 3–4 years before they become too damaged. However, bag quality is an issue particularly regarding the seams, which are crucial in obtaining an air-free environment. Timely delivery of the bags is critical, as is thorough advanced training of all partners in how to fill, store, and maintain the bags. They have also recognized the need to ensure that distribution channels are given more attention to help commercial sustainability postproject.	The long-term objective of the project is to reach 3 million households so that within 5 years, 50 percent of cowpea stored in the target areas will be in triple-layer plastic bags. The "one-time" cost for triple bagging is around US\$3, while the average increase in household income is estimated to be US\$150 (http://www.entm.purdue.edu/news/murdock_gates.html).

Source: http://www.entm.purdue.edu/news/murdock_gates.html.

NO. 21

Project title		OPTIMIZING THE INDIGENOUS USE OF PESTICIDAL PLANTS	
Project type	Harvesting/ storage	Project description	Outputs
Location	Ghana	<p>Smallholder farmers have problems with insect infestation during storage. This risk can lead to early sales of grain when market prices are low. Farmers could achieve a much higher price if they were to sell their grain later in the season, but they must control insect infestation during this period. Botanicals with pesticidal properties are already used by farmers as a means of reducing the impact of insect pests on stored commodities. However, farmers need reliable information on botanicals to support their decision making with respect to the quality of control they can expect when using a particular plant material. Farmers' traditional methods of botanical use are highly variable; the subsequent degree of success is equally variable.</p> <p>This project undertook surveys of the ethnobotanicals used by farmers in Ghana, and it undertook laboratory, field, and farm trials to assess their efficacy in replicated trials. The chemistry and bioactivity of plants was assessed to understand how active ingredients may vary depending on where, when, and how plant materials were collected. Mode-of-action trials assessed the mechanisms of efficacy (e.g., repellency, toxicity), and potential dangers to people (vertebrate toxicity) were evaluated.</p> <p>The project was undertaken within the Crop Postharvest Program (DFID, UK).</p>	<p>Botanicals are commonly used for the protection of all grains and legumes stored at the farm level with research showing effects against all common insect species that attack stored products. Often the same plant species used in crop protection have uses in livestock protection and for human medicine. Some pesticidal plant materials are common food additives and spices (chili, pepper, basil, orange peel). Using farmer participatory trials, it was shown that some botanicals used by farmers for stored product protection offer comparable protection to commercial synthetics when following best-practice application methods. Farmers were able to make botanical selections due to their own comparative analyses and base further decision making on this new knowledge. Reviving and modernizing farmer practice through the optimization of ethnobotanicals has shown that farmers can make cost-beneficial postharvest pest management decisions when appropriate application guidelines are followed. Botanicals can be used reliably and safely to treat food stored at the farm level. Knowledge on application concentration, method of application, preparation of botanicals, and duration of control expected can be used to promote botanicals as cost-effective and environmentally sustainable pest management for small-scale farmers. As plant materials are often collected from the wild, they offer a key incentive for habitat conservation, which is easily grasped by local stakeholders. They can, therefore, be tied into agricultural production programs related to land use, including land preparation technologies, forestry programs, biodiversity conservation programs, livestock programs (related to grazing land and their veterinary use), and human health programs.</p>
Project dates	January 1996– March 2002		
Value (US\$)			
		Outcomes and impacts	Future prospects
		<p>Project research evaluated botanicals to protect maize, millet, sorghum, rice, cowpeas, bambara nuts, and wheat. Twelve botanicals are widely used by subsistence farmers following local traditions throughout SSA for pest management in pre- and post-harvest and livestock sectors. Surveys carried out in the Ashanti region of Ghana with small- to large-scale farmers indicated that botanicals were used by 26 percent of all farmers with significant variation dependent on education level and locality. Studies in the three provinces in northern Ghana showed that 74 percent of farmers used botanicals, with 95 percent of farmers in the upper east region using pesticidal plants. Although comparative studies are not available, West Africa tends to have the highest rate of botanical usage, followed by East Africa and then Southern Africa. In the villages that were involved in research activities, the majority of farmers previously did little to protect their stored grain (>60 percent). The majority of farmers would sell their grain soon after harvest because they knew they could not maintain their grain in a good quality due to high levels of postharvest insect damage. Insecticides for treating grain are not widely available in rural villages, and the majority of villagers consider commercial synthetics to be too expensive in areas where they are available for purchase. Synthetics also pose problems through poor labeling, expiration, or adulteration; so farmers are worried that the synthetics they buy might be dangerous or ineffective. Their involvement in the botanical research has shown the farmers that they can maintain their grain quality over a longer period than without treatment, meaning that farmers can sell their grain later in the season when prices are higher. It also means that the quantity of grain is maintained with stocks for household consumption lasting longer. Thus, food security and incomes are increased when using botanicals. Our assessments showed that all farmers clearly preferred botanicals over synthetics for postharvest protection because they were financially cheaper to use and worked nearly as well as synthetics in most situations.</p>	<p>Our research showed that indigenous knowledge about botanicals does not easily spread across regions and ethnic groups because of lack of communication channels. Improving the means through which information can spread beyond local boundaries between farmers could assist in knowledge transfer. It has been argued that indigenous knowledge is also being degraded through HIV/AIDS and an increasing disregard for old traditions by the educated youth. National institutions can play a role in facilitating the spread of knowledge by repackaging it through the education system as well as other national programs of extension. Promotion of botanicals in pest control is happening all over Africa through the efforts of NGOs and national agricultural research systems (NARS). However, some of this promotion is perhaps ill advised, and pesticidal plants are sometimes promoted in an extemporized manner based on existing indigenous knowledge that has been taken out of context. For example, <i>Tephrosia vogelii</i> is traditionally used as a fish poison and contains the known toxin rotenone that has acute and chronic toxic effects in humans, including hepatotoxicity, nephrotoxicity, neoplastic, reproductive, and teratogenic effects. Its efficacy in the laboratory against stored grain beetles has been evaluated, and this work may have contributed to extension programs that promote the use of <i>Tephrosia vogelii</i> for on-farm stored grain protection, potentially leading to the toxin being ingested by people. The rational and considered approach taken to the botanical research in Ghana has paved the way for promotional activities to take place with minimal health risk and optimal gain to farmers who take up the outputs by ensuring that the science has been done before botanicals are promoted.</p>

Source: Dr. Steve Belmain, Natural Resources Institute, UK, Crop Postharvest Program projects R6501 & R7373.

NO. 22		IMPROVING SMALLHOLDER FARMER MARKET ACCESS	
Project title			
Project type	Utilization/ marketing	Project description	Outputs
Location	Uganda	<p>The project targeted the problem of poor market access of rural-based smallholder farmers who experienced this because of poor quality and low volumes of tradable produce due to heavy reliance on traditional practices of grain handling and storage. The output aimed at contributing to poverty reduction by increasing the competitiveness of rural farmers' maize, and it improved market access through high quality, large volume, and sustainable supply of produce in the marketing chain as a result of sustainable use of appropriate postharvest technologies and approaches.</p> <p>The government Plan for Modernization of Agriculture (PMA), which espouses a shift from subsistence to commercial production, lacks a pragmatic framework that enables smallholder farmers to work in coalitions with providers of postharvest technologies for improved produce quality, agricultural advisors, and extension agents, grain buyers, and resident NGOs. The output was therefore considered timely, and it provided the opportunity of trailblazing the role of the public sector in catalyzing links between the private sector, smallholder farmers, agricultural advisors, and NGOs through strategic coalition partnerships, especially, in enhancing farmers' access to profitable markets.</p> <p>The project was undertaken within the Crop Postharvest Program (DFID, UK).</p>	<p>The output mainly focused on maize enterprise. The strategy was primarily grain quality improvement through adoption of improved postharvest technologies, volume assurance through collective storage, and sustainable market supplies through links with major grain buyers. This entailed a shift from individualistic storage and marketing to collective storage and marketing. This required building of farmers' capacity in group dynamics, leadership, and entrepreneurial skills as the initial step for greater cohesion among them. The strategy helped in changing farmers' attitudes and building trust from the very beginning. Once the farmers had experienced the benefits of working together, they adapted and applied the same approach gained from maize marketing on other enterprises: sunflower, beans, sorghum, or beans that are cultivated in the districts where the output was trailblazed.</p>
Project dates	January– December 2005		
Value (US\$)			
		Outcomes and impacts	Future prospects
		<p>The lack of suitable postharvest technologies (dryers, shellers, stores, pest management packages) that optimize grain quality and quantity; lack of organized farmer groups involved in collective storage and marketing; poor market access and information flow; poor pricing; lack of credit access; and saving culture were identified as some of the major challenges contributing to poverty, especially of the smallholder farmers in the two districts. The second stage involved the identification of the coalition partners, depending on their core competencies, especially, in technology generation and dissemination (NARO), agricultural knowledge and provision (DAO), pro-poor rural development (NGOs: ASDI and BUCADEV), market information and pricing system provision (Afro-Kai), and output end users (farmer groups). Stakeholders held meetings in which the roles and responsibilities of each of the core coalition partners were defined. NARO trained farmers on the use and maintenance of the postharvest technologies and of the importance of grain quality standards and maintenance, provided primary processing equipment (shellers, dryers, sieves, moisture meters, weighing scales, fumigation kit including sheets, protective clothing, fumigants), and conducted technical backstopping. The district agricultural officers of Apac and Kiboga and the two NGOs helped in farmer group mobilization, sensitization, and monitoring of activities. Afro-Kai Ltd. provided market information as well as the market for the farmers produce. The end users—smallholder farmers, classified as poor, having less than 2 ha of land and living on less than US\$1.00 per day—produced and supplied the maize for collective storage and marketing. Other partners included National Council of Uganda small business organizations that provided training on entrepreneurship, leadership, credit access, and utilization. One of the training recommendations was at least a 30-percent representation of women in the group leadership. The local governments participated through the local councils, whose interests were in the tax regimes of produce leaving the subcounties and the sales of land for increased production. At the district level, district coordination committees were constituted between NGOs, farmer group representatives, and DAO to monitor project implementation processes and challenges for rapid response and feedback.</p>	<p>Linking farmers to market requires a consortium of experts, expertise, and stakeholders to effectively produce results. No single group working independently and in isolation can generate, utilize, or promote effective utilization of the required technologies, knowledge, and approaches. The output focused primarily on the postharvest subsector with the assumption that large volumes of maize were available. It was learned, however, that the demands of the grain buyer (Afro-Kai) far outstripped supply, and this called for investments production inputs (e.g., more land and improved seeds, fertilizers, and pesticides). Therefore, in linking farmers to markets, it is important that production as well as postharvest technology packages are considered in totality rather than segmenting them between different actors. Apart from encouraging farmers to produce for the markets, it is also important that they be given the latitude to decide how much they should keep for domestic food consumption; otherwise, there is no guarantee that financial security would ensure food security at home. Involvement of women in the group leadership in decision-making processes and in sharing the proceeds was considered a very positive lesson—first by empowering the marginalized and second by ensuring transparency and accountability of men to their families on income from produce sales.</p>

Source: Crop Postharvest Program Project R8422, <http://www.cphp.uk.com/projects/default.asp?step=6&projid=170>.

NO. 23

Project title		POSTHARVEST INNOVATION: ENHANCING PERFORMANCE AT THE INTERFACE OF SUPPLY AND UTILIZATION	
Project type	Harvesting/ storage, utilization/ marketing,	Project description	Outputs
Location	Tanzania	<p>Postharvest service provision and supporting research initiatives have focused on the development of technologies, with little attention paid to distinguishing between the needs and priorities of different households or to understanding delivery system constraints. This project aimed to identify constraints and opportunities at the supply-utilization interface associated with “responsiveness” and “demand,” respectively. The resulting practical insights and policy recommendations for in-country postharvest knowledge management expressly facilitated a more equitable or “inclusive” approach to addressing rural poverty.</p>	<p>Output 1. Institutional learning and change: improvements to understanding and effectiveness of LAs as agents of change advanced.</p> <p>Output 2. Facilitation of in-country PH knowledge management: Practical “insights” from current working practices developed, and improved practice recommendations generated.</p> <p>Output 3. Ability of diverse private sector players—farmers and commercial enterprises—to access and utilize relevant PH information, explored and improved.</p> <p>Output 4. Policy and implementation strategy recommendations to improve the performance of PH knowledge-management organizations and enhance related decision making by farmers and commercial enterprises generated and promoted.</p> <p>Project partners adopted a multistakeholder LA approach: key postharvest stakeholders from all sectors (public, private, voluntary) formed a LA with the same strategic aims as the project—better mobilization of national innovation systems to sustain the uptake and adoption of postharvest knowledge for the benefits of poor farmers—but set the specific challenge of exploring better ways of working and learning together.</p> <p>Core activities of PHILA were: collaborative research initiatives, internal information sharing (with an emphasis on information and communication technologies (ICTs), and engagement with other influential players in the postharvest system. Case studies critically examining current service provision practices; farmer demand mechanisms; and the bearing of current policies, their formulation, and implementation dynamics on postharvest situations were commissioned in the two countries. Insights from the LA process and the case studies are currently being used to generate practical guidelines and policy recommendations for wider in-country postharvest knowledge management.</p> <p>Inception workshops were used to promote and launch the LA, and final review workshops provided opportunities for further engagement, sharing of the case study findings, and consolidating learning. By commissioning diverse members to implement pivotal collaborative research, or through their more general collaboration or participation in these studies, PHILA sought to raise awareness and extend the individual and organizational capacity of its members. The research case studies, which focused on the interface of postharvest supply and demand, also involved and benefited other potential end users who were not necessarily PHILA members.</p>
Project dates	January 2005– January 2006		
Value (US\$)	\$220,000		
		Outcomes and impacts	Future prospects
		<p>PHILA has provided a safe and effective space for diverse key individual stakeholders from multiple organizations within the national innovation systems to work and learn together and to improve interorganizational relationships.</p> <p>PHILA has promoted recognition of the diversity of rural circumstances and livelihoods to ensure that service provision is more responsive in meeting the needs and priorities of different groups, including poorer individuals and households.</p> <p>PHILA has actively sought to share all of its findings on enhancing postharvest performance at the interface of supply and utilization with key players in the national innovation systems; and PHILA itself provides a living legacy to continue and consolidate this work through its expanding membership and through the PHILA Web site (http://www.nri.org/PHILA/).</p>	<p>PHILA provides a model for similar postharvest LAs to use and would be a good forum for discussing any future postharvest-related research activities in either Tanzania or Zimbabwe, and its structure could be scaled up to have more regional representation as necessary. Its short time frame (11 months) followed by a change in funding approach of DFID led to PHILA becoming dormant in terms of further large-scale activities needing external funding. However, the institutional and personal links have not been dormant, and significant interactions still occur.</p>

Source: Department for International Development UK, *Crop Postharvest Projects R8460*; Mr. Mike Morris (ex NRI now WWF); Dr. T. E. Stathers (NRI); Dr. B Mvumi (UZ); Mr. W. Riwa (PHS, Ministry of Agriculture, Tanzania); www.nri.org/PHILA/.

NO. 24

Project title	EXPLORING THE SCOPE OF COST-EFFECTIVE AFLATOXIN RISK REDUCTION STRATEGIES IN MAIZE AND GROUNDNUT VALUE CHAINS TO IMPROVE MARKET ACCESS OF THE POOR IN AFRICA		
Project type	Project description	Outcomes and impacts	
Location	<p>The project objectives are to</p> <ol style="list-style-type: none"> 1. Estimate the economic consequences of aflatoxin contamination on human and livestock health, farmer livelihoods, and trade 2. Develop a database of the prevalence of aflatoxin and the effectiveness of control strategies along value chains for groundnuts in Mali and maize in Kenya 3. Perform risk analysis to identify cost-effective control strategies for reducing aflatoxin risk 4. Map the maize and groundnut value chain and investigate the knowledge, awareness, attitudes, practices, and perceptions of aflatoxins by the actors within those value chains as well as their willingness to adopt and pay for aflatoxin testing and control strategies <p>Led by IFPRI and partnered with CIMMYT, the International Crops Research Institute for Semi-Arid Tropics (ICRISAT), ACIDI-VOCA, the University of Pittsburgh, the U.S. Uniformed Health Service, Institut d'Economie Rurale (IER), and Kenya Agricultural Research Institute (KARI). Funding from Bill & Melinda Gates Foundation.</p>	<p>The project is still in early stages, but it is expected to provide empirical evidence of the cost effectiveness of technologies currently used in developing countries to reduce the risk of human and animal exposure to aflatoxin contamination and to understand what is preventing these technologies from being adopted as control strategies in Africa. With this evidence and understanding, it is expected that identified cost-effective measures will be implemented, thereby clearing a path for farmers to produce aflatoxin-free crops and improving market access for poor farmers in Sub-Saharan Africa. The case studies of interest are groundnut and maize value chains in Mali and Kenya.</p>	
Project dates			2008–present
Value (US\$)			\$220,000

Source: Dr. Clare Narrod, IFPRI, <http://www.ifpri.org/pressroom/briefing/impact-aflatoxin-kenya-and-mali>.

NO. 25

Project title		KENYA MAIZE DEVELOPMENT PROGRAM (KMDP)	
Project type	Harvesting/ storage, utilization/ marketing	Project description	Outputs
Location	Kenya	<p>KMDP was originally funded under a 4-year cooperative agreement to increase rural household incomes but has been extended. KMDP boosts household incomes by raising productivity, improving the effectiveness of smallholder organizations, and increasing access to agricultural markets and business support services. Led by ACDI/VOCA, the program involves a diverse consortium of partners within the maize value chain, including the Grain Growers Association of Kenya, Farm Input Promotions Africa Ltd. (FIPS), and the Kenya Agricultural Commodity Exchange (KACE).</p>	<p>Established a network of market information centers serving as locations for prices and trade information within local and regional markets. Through these centers, buyers are able to post purchase bids while farmers can review offers and sell their stocks to buyers. Kenyan farmers have been able to take advantage of the widespread use of mobile phones to acquire quick and accurate information through the short messaging system (SMS).</p> <p>Supporting 80 farmer associations (in 2008) with a total membership of approximately 250,000 farmers, and training an average of 12,000 farmers each quarter in business practices, particularly business skills for association leaders and their members.</p> <p>Training curricula is expanded to include a business start-up training program targeting entrepreneurs in the agricultural and business sector.</p> <p>Published the Kenya Maize Handbook, a summary of the maize production process and industry trends</p> <p>Facilitated the first-ever private sector-focused maize industry business fair in September 2003 to bring together over 3,000 farmers and 200 business service providers to create effective business links. Since then, KMDP has held annual business fairs with as many as 80 exhibitors and 20,000 people participating in the 2008 event, resulting in smallholder producers connecting directly to market service providers and thereby reducing the number of middlemen in the value chain.</p>
Value (US\$)	\$11.2 million		Outcomes and impacts
		<p>KMDP has achieved nearly tripled smallholder maize yields from a baseline output per unit of 8 bags per acre (each bag weighs 90 kg) to an average of 32 bags per acre, only dropping to 25 bags per acre when fertilizer prices increased and farmers were forced to reduce their usage. This has resulted in increased net earnings of \$206 million for 370,000 smallholder farmers (almost 30 percent of whom are women). Of these farmers, over 100,000 have completed the project-designed training course in Farming as a Family Business. The training provides practical information on improved production methods and better crop marketing through organized markets systems. This dramatic growth in smallholder productivity is brought about by improving farmer business management, tailoring input distribution specifically for smallholders (new types and smaller packages), and bulk purchasing and marketing through the groups. Smallholder farmers are learning to adhere to international quality and linking directly with private sector business development services. Through KMDP, there is increased demand for business service; it provides links and awareness of the services and products available while addressing constraints on the delivery of these services.</p>	

Source: Catharine Phiri, ACDI-VOCA, Washington DC.

NO. 26		NAADS UGANDA	
Project title		Project description	Outputs
Project type			
Location	Uganda	The National Agricultural Advisor Services (NAADS), a World Bank-funded agricultural extension initiative in Uganda, aims to disseminate improved production and postharvest technologies for smallholder producers. The program was launched in the year 2001 and is ongoing for another 25 years.	A survey by IFPRI found that the proportion of households recently becoming aware of drying technologies, storage facilities, grading practices, information on prices and markets, and collective marketing practices was significantly higher in trailblazing NAADS regions, ranging from 8 percent to 22 percent of households. The share of marketed output was slightly higher among households in NAADS subcounties (28–33 percent) compared to their counterparts in non-NAADS subcounties (24 percent).
Project dates	2001-2008	The NAADS program is in its fourth year of its first phase of implementation. The program design stipulates for a mid-term review (MTR) of the program in the third year of implementation. The general objective of the MTR was to assess NAADS impact and intermediate outcomes to date as well as the emerging good practices and lessons learned. The MTR also aimed at reviewing program design based on the diverse lessons and experiences arising out of implementation.	
Value (US\$)			
		Outcomes and impacts	Future prospects
		NAADS performance was looked at from two angles: the overall national perspective and district perspective that focused on Kabarole and Mukono districts. The review findings reveal high levels of participation and decision making by farmers' groups and farmers' fora (64 percent in Lira, 87 percent in Soroti, and 75 percent in Kabarole). The Scanagri MTE survey found that 88 percent of the farmer groups believed they had greater ownership of the extension system. In addition, the National Service Delivery Service Survey undertaken by UBOS showed that farmers in NAADS districts express a greater demand for specialized extension/advisory services than those in non-NAADS districts. The Scanagri MTE survey also found high levels of awareness about NAADS; around 52 percent of non-NAADS farmers' groups surveyed were aware of the program and knew it provided training to farmers. Preliminary evidence shows that NAADS groups have adopted new technologies (including postharvest) after exposure to TDS and training services. Sixty-four percent of the farmers' groups reported replicating some aspects of the technologies provided under NAADS. Independent econometric analysis of survey data also showed a positive impact of NAADS on household crop production and a high return to investment.	The MTR suggest a production-oriented impact of the NAADS programs so far, with improvement in postharvest technologies and use of marketing information lagging behind. This situation needs to be corrected quickly before the potential gains in yields, derived from the observed increase in adoption of new production technologies, cause prices to collapse, which could reduce the gains to improved production technologies. There are intended strategies to help improve the situation. The PMA marketing and agro-processing strategy (MAPS) is the first key that sets out to address issues relating to collective action (support to farmers' organizations, cooperatives, and outgrower schemes); physical infrastructure (roads, energy, telecommunications, markets, agro-processing units, and postharvest storage); policies and legislation (commodity exchange and warehouse receipts, grades and standards, and taxation); and market information. These will be critical for creating the incentives for reducing post-harvest losses

Source: World Bank

NO. 27

Project title		IMPROVEMENT OF POSTHARVEST TECHNOLOGIES FOR FONIO	
Project type	Threshing, decortications, drying, marketing, product innovation.	Project description	Outputs
Location	Burkina Faso, Guinea, Mali	<p>The project was implemented in response to requests from processors, most of them women, who were encountering difficulties in postharvest handling and processing of fonio to supply the rapidly growing market in urban areas of the West Africa region as well as diaspora populations originating from the region. Executed by CIRAD, supervised by FAO, and co-funded by CFC, the project adopted a multidisciplinary approach involving breeders, machine fabricators, engineers, technologists, and socioeconomists. Project activities were carried out in all three countries around the following five specific objectives:</p> <ol style="list-style-type: none"> 1. Improve on-farm postharvest technologies 2. Develop processing techniques that are appropriate for the needs of end users (farmers' groups, artisans, and small businesses) 3. Improve understanding of the needs of consumers and development of marketing chains 4. Raise awareness on fonio postharvest operations in the target countries 5. Support local fabrication of processing machines for fonio 	<p>Objective 1:</p> <ul style="list-style-type: none"> • Improved technologies and techniques for threshing and winnowing <p>Objective 2:</p> <ul style="list-style-type: none"> • Machines for dehusking developed • Improved technology for winnowing dehusked grain and for sorting, precooking, and drying fonio grain <p>Objective 3:</p> <ul style="list-style-type: none"> • Marketing channels and consumer requirements for fonio better understood <p>Objective 4:</p> <ul style="list-style-type: none"> • Information on fonio postharvest systems disseminated in West Africa • A regional network developed and information exchange fostered <p>Objective 5:</p> <ul style="list-style-type: none"> • Local fabrication supported
Project dates	1999–2004		
Value (US\$)	1,451,582		
		Outcomes and impacts	
		<p>The project developed technologies for the different facets of the postproduction chain, including on-farm threshing, cleaning, dehusking, winnowing, washing, precooking, and drying. Key lessons from the approach taken include: there was evidence of economic incentives to facilitate adoption of technologies developed; technologies developed did cover the entire postproduction chain; national research institutions from the three beneficiary countries as well as key stakeholders including processors and machine fabricators were involved; a market-oriented approach was taken with the requirements of the intended consumers of fonio guiding the development of the technologies.</p>	

Source: FAO/CFC/CIRAD (2004).

Annex 3. BENEFITS, COSTS, AND DEGREE OF ADOPTION OF TECHNOLOGIES

LOCATION IN VALUE CHAIN	TECHNOLOGY	BENEFITS	COSTS	DEGREE OF ADOPTION	PROSPECTS
CROP IMPROVEMENT					
All farming situations and especially maize grain.	Grain varieties with better PH characteristics.	Potential to maintain quality by resistance to insect infestation.	Likely to be genetically modified (GM) crop and would need purchase from seed supplier, so more expensive than traditional and improved local varieties. Potential official resistance.	No variety yet available commercially, so no adoption.	Uncertain as development may not be possible.
HARVESTING					
Rice farming with fields accessible to mechanization, for large farmers or groups of smallholders	Mini-combine harvester.	Harvesting quicker and with lower labor requirement. Improvements in quantity and quality from more timely postharvest operations (project 18).	High financial cost relative to farm incomes. Would need to be purchased by farmer groups or harvest contract service providers.	Technology developed in Southeast Asia by IRRI but not yet introduced into Africa.	Will become more relevant as the African rice industry expands.
THRESHING, SHELLING, WINNOWERING					
Rice/wheat farming, for large farmers or groups of smallholders	Mechanized thresher/winnower.	Threshing quicker and with lower labor requirement. Improvements in quantity and quality from more timely postharvest operations (project 19).	High financial cost relative to farm incomes but good payback. Would need to be purchased by farmers' groups or provided through contract farming schemes.	Technology developed in Southeast Asia by IRRI and now being introduced into Africa as part of current project activities (project 19); significant adoption typically takes 8–10 years. Also in West Africa (Mali and Senegal) the ASI thresher successfully introduced.	Will become more relevant as the African rice industry expands.
Maize farming, for large farmers or groups of smallholders.	Mechanized shelling.	Shelling quicker and with lower labor requirement.	High financial cost relative to farm incomes. Would need to be purchased by farmer groups or provided through contract farming schemes.	Technology of hand-driven and mechanized shellers well established and have been extended for many years (e.g., project 9), but adoption rates low due to costs.	Becoming increasingly relevant as labor constraints affect production.
DRYING					
Maize farming by smallholders in areas where there can be rainfall during the drying period.	Tarpaulin to assist drying of maize.	Reduce physical losses and potential mycotoxin production as grain is protected from rainfall.	Relatively high financial cost for smallholders. If good quality tarpaulin purchased, a life of at least 5 years possible. Affordable credit or subsidy.	Successful adoption by farmers in Uganda.	Particularly useful for very small-scale producers. Increasingly useful as weather conditions become more variable because of climate change.

continued

(Continued)

LOCATION IN VALUE CHAIN	TECHNOLOGY	BENEFITS	COSTS	DEGREE OF ADOPTION	PROSPECTS
Maize farming by farmer groups or large farmers, in areas where sun drying is slow or difficult.	Maize drying crib (Boshoff type).	Drying more quickly in a crib and sheltering maize from rain and pest attack leads to improvements in quantity and quality, including reduced mycotoxin contamination.	Relatively high financial cost for smallholders and life of wooden structure limited by termite damage. Affordable for farmer groups.	Have been promoted by projects in hot, humid areas, but adoption appears to have been achieved through subsidy.	Good prospects in humid areas where small-scale producers are content to store collectively.
Rice farming by large farmers or groups of smallholders.	SSR low-cost dryer for paddy rice.	Drying quicker leads to improvements in quantity and quality from more timely postharvest operations (project 18).	High financial cost relative to farm incomes (US\$100 for 1 ton capacity). Purchase by large farmers or farmers' groups or supplied by contract farming schemes.	Technology developed in Southeast Asia by IRRI, but preferred option is to encourage farmers to send paddy to contractors or millers for drying, not to dry their own paddy. Not yet introduced into Africa.	Uncertain
Rice farming by large farmers or groups of smallholders.	Flatbed dryer for paddy rice.	Drying quicker leads to improvements in quantity and quality from more timely postharvest operations (project 18). Offers good payback in Vietnam.	High financial cost makes this type of machine only suitable for drying contractors and millers.	Technology developed in Southeast Asia by IRRI and 7,000 installed in Vietnam. Ten flatbed dryers installed in Uganda (project 9).	Will be more relevant and cost effective as the African rice industry expands.
STORAGE STRUCTURES					
a) Sack storage—increasing storage capacity in small increments					
i) Open-weave sacks					
Smallholder and large-scale storage, short- or long-term storage.	Jute or polypropylene sacks.	Convenient both as a means of storage and to pack grain for marketing.	Low cost, but does not limit pest damage, so reliance on pest management using pesticide is needed for storage periods of more than 3 months.	Widespread organic adoption, now very popular with smallholders for storage in the house.	Likely to grow without the need for promotion except among the poorest groups.
ii) Hermetic sacks—kill pests due to airtight environment					
Smallholder (rarely large-scale) storage, where at least 2 months' storage anticipated	Super bags.	Can significantly limit deterioration of grains in storage.	Relatively high costs (US\$40/ton) but less labor intensive than triple bagging. Cost efficiency based on reuse, so may be unsuitable container for marketing grain.	Increasingly available in SSA but still low adoption rate.	Could see use as a fixed storage method for grain to be used in household subsistence and also preservation of seed grain.
	Triple bagging.		Relatively low cost (US\$18/ton) but more labor intensive than super bags. Cost efficiency based on reuse so may be unsuitable container for marketing grain.	Widespread successful promotion for cowpea storage.	Could be promoted for grains storage, mostly as a fixed storage method for grain to be used in household subsistence.
b) Improved, open-access farm store					
Smallholder storage in a wide range of environments.	Fired brick storage.	Can significantly limit deterioration of grains in storage, long life, easily available construction materials, can be built with good capacity (3 tons), easy access.	Relatively high cost (equivalent to about 1 ton of grain).	Some successful but not widespread adoption in Zimbabwe.	Uncertain.

(Continued)

LOCATION IN VALUE CHAIN	TECHNOLOGY	BENEFITS	COSTS	DEGREE OF ADOPTION	PROSPECTS
c) Sealed stores—prevents pest access, when placed in store grain needs to be well dried and pest free					
Smallholder storage in arid and semiarid environments.	Mud silo.	Mud silo. Can significantly limit deterioration of grains in storage. Provides local employment for construction and uses readily available local materials.	Relatively low cost but requires significant maintenance.	Examples of successful adoption in northern Ghana.	Has potential in appropriate climatic zones where there are mud silo-building skills.
Smallholder storage in a wide range of environments.	Metal silo.	Can significantly limit deterioration of grains in storage. Provides local employment for construction. Wide range of benefits (see box 3.2).	Relatively high cost (US\$120–450) but only requires modest maintenance. Supply of suitable materials can be limited.	Very extensive adoption in Central America after 20 years of a social marketing approach.	Despite failures in Africa to date, could do well with a social marketing approach.
	Plastic stores.	Can significantly limit deterioration of grains in storage and requires only modest maintenance.	Relatively high cost (US\$200) for 1- to 1.5-ton capacity.	Manufactured locally in Namibia but still to achieve significant adoption due to cost.	Shows good potential as a durable, locally available store.
Large-scale storage for groups or traders.	Plastic silos.		Relatively high cost, can be constructed from modified water tanks.	To date, only tested experimentally with cowpeas, combined with phosphine fumigation.	Shows good potential as a durable, locally available store.
d) Hermetic stores—kill pests due to airtight environment					
Large-scale storage for groups or traders where grain movements in and out of storage are infrequent and storage periods are at least 3 months.	Sealed plastic envelopes.	Can significantly limit deterioration of grains in storage. Mobile storage structure with a life time of several years.	Relatively high cost for initial investment (US\$180–220/ton). Staff needs to be well trained in use.	Have been adopted in several locations in Africa.	Very useful for long term storage in situations where normal grain management is problematic.
PEST MANAGEMENT IN STORAGE					
All farm and large-scale storage situations, regardless of length of storage period.	Improvement in store hygiene.	Can significantly limit physical PHL in store with little or no financial outlay required.	Increased labor requirement.	Poor adoption, but very little effort to encourage farmers to adopt more hygienic practices.	Excellent prospect for significant impacts on PHL.
Smallholder and large-scale storage where more than three months' storage anticipated. Compatible with a wide range of storage methods including jute and polypropylene bags.	Synthetic insecticide.	Can significantly limit deterioration of grains in storage, relatively simple to apply.	Relatively expensive for smallholder but cost effective in many situations. Imported and negative associations of food treatment.	Widespread adoption but problems with adulteration and of poor training of farmers in usage.	Likely to be phased out gradually. However, with more emphasis on grain, quality could see a rise in usage in the short term.
	DE.	Can significantly limit deterioration of grains in storage, relatively simple to apply. Avoids toxicity issues of insecticides and can confer organic status.	Relatively expensive but could probably be made available at similar cost to synthetic pesticides. Could be produced locally, so offering import substitution and potential export market.	Not yet available although registered in some countries.	As use of synthetics is phased out, DEs would be expected to offer an effective alternative in many situations.
Smallholder storage of small quantities of grain.	Solarization.	Could significantly limit deterioration of grains when combined with sealed storage.	Inexpensive means of disinfecting grain prior to storage.	Has been adopted on a small scale for cowpea treatment prior to sealed storage in Ghana and Uganda.	Larger-scale solarization systems would be suitable for grains but needs to be developed.

continued

(Continued)

LOCATION IN VALUE CHAIN	TECHNOLOGY	BENEFITS	COSTS	DEGREE OF ADOPTION	PROSPECTS
Large-scale producers, farmers groups, traders, and millers, where storage of grain in bags or in silos exceeds 3 months.	Fumigation with the gas phosphine.	Can significantly limit deterioration of grains.	Relatively inexpensive (US\$ 1–2 per ton) means of killing insect pests on grains, but treatments may need to be repeated every 4–6 months.	Widely adopted in SSA for treatment of large-scale stores (e.g., treatment of bag stacks under gas-tight sheets or treatment of small or large gastight storage structures). In several African countries, smallholders are prohibited from fumigating.	Will continue as the main mean of killing insects on grain in large-scale storage. Service provided by commercial pest control companies, although standards are sometimes very low.

Annex 4. OVERVIEW OF PHL-REDUCTION PRACTICES BY DIFFERENT ORGANIZATIONS

This document is a brief review of activities undertaken to reduce PHL for grain staples in SSA, with particular focus on East Africa. The project is concerned with PHL reduction for grain crops, mostly at the farm and village level. Losses will be defined as: physical (weight and quality), opportunity (failure to market or inability to get a reasonable price), and external (losses through the need to use pest control or socio-environmental costs of pesticides).

The following table summarizes the information obtained from Internet searches, discussions, and personal experience. The detailed information about the PHL-related activities of each organization is available in the project files and available upon request.

	THEMATIC FOCUS OF THEIR POSTHARVEST WORK									GEOGRAPHICAL FOCUS			
	Postharvest pest and disease management	Storage structures	Community grain stores or warehouse receiving	Market information	Market access	Postharvest awareness raising/communication/info.	PH learning alliances/innovation systems	Large scale grain storage	PH equipment	East Africa	West Africa	Central Africa	Southern Africa
Lead implementing organization													
Action Aid		X											
African Agricultural Capital	X				X					X			
AGRA				X	X								
Catholic Relief Services			X								X		
Concern Worldwide					X					X	X	X	X
ENDA Zimbabwe		X											X
EAGC			X										
Faida Market Link Company Limited (FaidaMaLi)				X	X								
Farm Concern International				X	X								
FEWS Net Famine Early Warning Network				X		X				X	X	X	X
FoodNet				X		X			X	X			
INADES Formation Tanzania	X				X	X	X			X			
Intercooperation/Rural Livelihoods Development Co.				X	X	X				X			
Kilimo Trust										X			
MVIWATA Mtandao wa Vikundi vya Wakulima Tanzania				X	X		X			X			
NRI	X	X	X	X	X	X	X	X		X	X		X
NetHope				X						X	X	X	X
Oxfam Ireland				X						X			

continued

(Continued)

	THEMATIC FOCUS OF THEIR POSTHARVEST WORK								GEOGRAPHICAL FOCUS				
Practical Action			X	X	X					X			X
RATES (Regional Agricultural Trade Export Support)			X	X	X	X		X		X			X
RATIN (Regional Agricultural Trade Network)				X		X				X		X	X
SNV (Netherlands Development Organisation)			X		X					X	X		
Winrock International					X	X				X	X		
World Vision	X	X								X	X	X	X

Annex 5. COMMUNITY GRAINS BANKS: HISTORY AND LESSONS

Community cereal banks come in a variety of forms and have numerous different purposes, including the following:

- improving food supply over the agricultural cycle, especially during the hungry season and extended drought periods;
- providing a locally based, in-kind savings and loan facility;
- helping to stabilize commodity prices locally through grain storage (reducing the intra-annual price variation, temporal arbitrage);
- providing a nearby and reliable market for produce;
- providing an uncommon form of community-based insurance against covariate risk;
- reducing PHL;
- reducing the “overselling” problem of grain by farmers;
- providing a local emergency buffer stock of food;
- strengthening village-level organizational capacity;
- increasing real incomes;
- assisting local producers to market their grains in urban markets with higher prices.

The main features of grain cereal banks are described below.

Initiation process

Grain cereal banks are frequently initiated by agencies external to the community, often following participatory discussions, needs assessments, and suggestions. However, historically, grain cereal banks have been integral parts of many communities’ collective food security coping systems. In India, cereal banks are a descendent of the traditional system of grain golas, in which surplus grains were collected postharvest into a common pool that was controlled by the village head and from which disbursements were largely discretionary (Bhattamishra and Barrett 2008). The indlunkhulu (big house) practice in Swaziland and the zunde ramambo in Zimbabwe were traditional social welfare systems whereby food crops were grown on common land using communal labor to protect

against food insecurity within the community (Stathers et al. 2000; Itano 2005; Kaseke 2006). Zunde ramambo originally existed at three hierarchical levels: household (the husband’s granary was used to supply whichever wife’s was depleted first), the village (the village had a zunde field, and all donated their labor to feed the disadvantaged when their food ran out), and the chief (the community provided labor to produce food for the disadvantaged and for guests fed by the chief). The ancestral Zunde scheme phased out in the 1950s due to many reasons, including marketing practices undermining the incentive to work communally and the introduction of government feeding programs (Stathers et al. 2000). In Zimbabwe and Swaziland, the HIV/AIDS epidemic has resulted in these traditional institutions being revived to help support the growing numbers of orphans and vulnerable children.

However, most community cereal banks are set up as donor-conceived interventions and not initiated as traditional community coping strategies, which may be the key factor behind their frequent failure. This intervention became popular in the 1970s following serious droughts (FAO 1994). NGOs that have sponsored cereal banks in West Africa, especially in Sahelian countries, include the CRS, Fondation Nationale pour le Développement et la Solidarité (FONADES), Afrique Verte (Burkina Faso), Institut Syndical pour la Cooperation au Development (ISCOS), ACOPAM project of the International Labor Office, and SNV. German Technical Assistance (GTZ) and FAO have also supported cereal banks in the past. According to an exploratory report, in 2005 no externally initiated community grain cereal banks existed in Southern Africa (Langyintuo 2005). However, the NGO Sacred Africa Africa, supported by the Rockefeller foundation, has helped farmers in western Kenya who are frustrated by poor marketing conditions by setting up 25 cereal banks, despite the poor history of collective marketing (Mukhwana 2009). The Millennium Villages project has supported cereal banks in 10 African countries in an arrangement whereby farmers who received free seed and fertilizer inputs then provide the project cereal banks with three bags of maize grain after harvest. Part of this grain is used to support a school feeding program

in the village, and the remainder is kept and sold during the hungry period.

In community cereal banks, grain is typically bought just after the harvest when prices are low, either from the village or elsewhere; it is then stored until it is needed, when it will be sold to the villagers at a reasonable price (Kisangani 2005). Because the cereal bank is nearby, villagers save on time and transport costs. If initiated by an external agency, decisions need to be made about whether they donate a conditional loan (grain or cash) or a gift, or whether the community will contribute the initial grain stock through farming a communal field or making individual contributions. Starting the cereal banks with both cash and grain may be a good solution. Cash will help the management committee learn about the realities of the grain market, competition with traders, and aspects of how formal banking systems work, although there could be the temptation to use the cash for other purposes. Starting with only grain may result in the village seeing the cereal banks as just a source of food aid (Kisangani 2005). NGOs are often involved in initiating community cereal banks, with involvement from national government departments on storage management and so on. It is difficult to get a feel for just how many community cereal banks exist, but they are particularly popular in the Sahel. During a 1998 workshop organized by the CRS on community-level grain storage projects (cereal banks), the following was discussed: Why do they rarely work, and what are the alternatives? A 1991 study was referred to, which found that 3,300 cereal banks had been established in the Sahel, half of which were in Burkina Faso; by 1998 it was estimated that this number would have increased to over 4,000 (CRS 1998; Gergely et al. 1990).

Community ownership

Practical Action point out that although there is no blueprint process, the decision to set up a cereal bank should be based on a commonly felt need in the village, such as a grain shortage during extended drought periods or prior to harvest (Kisangani

2005). As there should be community ownership of the store, it is important that adequate consultations be made with all categories of people in the village regarding the aims of the grain cereal banks, the type of store needed, its location, how to access the initial grain to get started, whether it should be run for profit or just to serve the interests of the community alone, which types of grains should be banked, and how it will operate. Additionally, the members need to agree in advance on the activities and supervise them.

The cereal bank's members need to elect a management committee, which might have the following composition and responsibilities (Kisangani 2005). These members must be honest, upright, dynamic, literate, and dedicated to the well-being of the village. The members should also be representative of the diversity within the community (gender, age, class, etc.). The committee is likely to need additional training, particularly on the accounting system.

The storage facility

The storage facility will vary by community. It can be built by the villagers using either local materials or more expensive purchased materials, but it must aim to exclude rodent, bird, and insect pests. Borrowing or renting a store may be easier at the beginning, but a clear understanding with the owner is required to prevent disruption during the cereal bank's operations. The location needs to be acceptable to and easily accessed by all; it should be somewhere secure where it can be safely guarded. The members need to decide how much grain the cereal bank needs to store in order to take the village through the hungry season and whether they have the resources to safely purchase and store that capacity of grain.

OPERATING THE CEREAL BANKS

Buying

Buying usually happens just after the harvest when the market price is at its lowest; the cereal bank buys first from members, then from surrounding villages, then from traders.

POSITION	RESPONSIBILITIES
Chairperson	Responsible for and overseeing of the cereal bank's activities. Main point of contact with the outside world.
Secretary	To record all the administrative and accounting operations of the cereal banks. Will need to be trained in the accounting system.
Storekeeper	To take in the grain that has been bought by the cereal banks and subsequent sale of the grain. Responsible for the upkeep and maintenance of the store and for maintaining and safeguarding the condition of the grain inside it. Will need to be trained in the accounting system and good grain-storage management.
Treasurer	In charge of the money. Needs to have simple accounting skills to effectively manage a system of four books (the book of: the treasurer, the purchasing officer or buyer, the secretary, and the storekeeper) and double-entry bookkeeping.
Buyers	Arrange for the cereal banks to buy grain at the best possible price, sometimes traveling long distances and arranging transport for the grain back to the village. Will need to be trained on the accounting system and on effective purchasing.

The cereal bank may decide to pay its members a slightly higher price than the prevailing market price. The location of the cereal bank will determine its buying policy. If it is located in a village that suffers from chronic food deficits, it may make more sense to buy grain from outside the village.

Selling

The cereal bank members need to decide on when to start selling the grain (e.g., should it be throughout the year, just during the hungry period, or only when the market price reaches a certain level?).

The bank sells first to its members, and it may decide to sell only to particularly vulnerable members of the community; also, it may set limits on the maximum quantities an individual can purchase. The sale price should be slightly lower than the prevailing market price, but at least equal to or more than the cost price. The grain should be sold in both large and small amounts, as not everyone can afford to buy large amounts at a time (Kisangani 2005). Revenues are used as a revolving fund to refinance the operation the following year.

FREQUENT PROBLEMS WITH COMMUNITY CEREAL BANKS AND SUGGESTED SOLUTIONS

Competing with the commercial grain traders

Cereal banks are often set up to overcome grain shortfalls in a particular village or area; they have to purchase grain from other places and move it back to their village. This spatial arbitrage (trading between geographical locations) is a highly competitive business, and profit margins are thin; only economic agents with good management skills are likely to succeed or survive (CRS 1998). In addition, cereal banks often aim to reduce the intra-annual price variation of grains for villagers. This temporal arbitrage or speculative storage (buying and storing grain when the price is low and selling it during high price times) is also risky, with much smaller profit margins than frequently assumed after the costs of transportation, handling, storage structure rental or depreciation, empty sacks, storage insecticides and treatment, pallets, guarding, licensing, and other aspects are deducted.

Flaws in the forced-sales rationale behind creating cereal banks

A major rationale for the creation of cereal banks is that “farmers are often compelled by immediate and pressing domestic financial needs to sell most of their meager harvest at very low prices during the harvesting period in order to meet their needs. Invariably, they are then compelled

to buy grain at very high prices during the hungry season” (CRS/ Ghana 1994, as cited in CRS 1998). However, several studies of farmers’ grain sales patterns (Goetz 1990; Reardon and Mercado-Peters 1993) show that this isn’t the case and that farmers tend to spread their sales of grains throughout the year. In a village in a semiarid central zone of Tanzania, one of the poorest households was found to strategize by using their casual labor income to purchase grain during the period immediately after harvest (when the grain price is lowest) and then to store this along with the tiny amount they had harvested themselves for use during times when the grain purchase price was higher (Stathers et al. (forthcoming)).

Running at a profit

On average, cereal banks sell their grain at a 10 percent discount (CRS 1998). However, by selling or lending grain at below-market rates, these cereal banks have tended to lose money, decapitalize themselves, and eventually go out of business. The CRS 1998 workshop estimated that of the 4,000 cereal banks set up in the Sahel, only ~1,000 were continuing to buy and sell grain; the rest were out of business. Another study found that only 1 of the 100 cereal banks that FAO had created in Niger had survived more than a few years, and that was because it was receiving support from another project in the area (CRS 1998). Grain marketing is a competitive business, and the margins are generally thin; sales at below-market rates are likely to generate losses.

Lending grain

Cereal banks have shown that lending grain is a difficult business; defaults are common. Villagers who borrow grain from cereal banks frequently feel little moral obligation to pay back their loans because they perceive the cereal banks as a social institution. Defaults on grain loans are a major cause of bankruptcy of cereal banks (CRS 1998).

Management problems

Strong, skilled leaders and plenty of training are needed prior to starting any cereal bank operations. To run at a profit, cereal banks need to adopt businesslike approaches, which are often at odds with the perceived “social” purpose of the cereal banks and local pressures within the community. There is often a high turnover of cereal banks management committee; and often after training (particularly if the management position was unpaid), an ongoing skills deficit and training demand result.

Poor postharvest and storage loss reduction skills

Cereal banks often claim to aim to reduce the high PHL suffered by individual households due to poor postharvest grain management. However, unless the cereal banks management committees have strong postharvest management skills, large losses can occur during storage, handling, and transportation in the cereal banks. One extreme example is that in Niger, one cereal bank lost 49 percent of the millet stored in it, compared to farmers' estimated storage losses of 3–5 percent (CRS 1998).

Community ownership and understanding

If the cereal bank is perceived as a social welfare organization and the community feels little ownership or responsibility toward repaying its debts to the cereal bank, it is likely to cease operations as soon as external support ends. There is often little or no incentive for managing collective goods in an effective way, and this quickly results in bankruptcy of the collective activity. In areas where there are frequent donor injections of cash or food, there is little incentive by either the management or the community to operate the cereal bank's profitability when the expectation is that a donation will come and restock the cereal banks. In western Kenya, SACRED Africa has supported 25 cereal banks in order to improve market access for farmers; the members of these cereal banks have to pay a registration fee and buy shares equivalent to two bags of grain, and these conditions may help improve members commitment. However, it still remains to be seen how these cereal banks will manage when SACRED Africa has withdrawn its sizeable support arrangements.

Reaching the target beneficiaries

Richer households can benefit by buying up all the grain in the bank and reselling it at a profit. This can be avoided by having fixed quotas on how much each member or household can buy, or specified purchase-quantity-over-time rules.

The poorest in the community still may not be able to benefit from the cereal banks if they don't have funds to purchase grain. In response, the cereal banks could decide to set up a social welfare system. A contribution or percentage from each sack of grain that is bought is put into a fund to assist the poorest in the community in accessing grain. But this amount would need to be factored into the sale price, if the cereal bank is to be able to run sustainably.

If the cereal bank decides to allow people to buy on credit, it needs to predetermine how many people are likely to need

credit and how much grain it can afford to sell that way, as well as how to deal with people who do not pay their debts. However, some cereal banks operate as in-kind savings and lending facilities, such as lending grains to members during the hungry season, with members repaying their loans in-kind after the harvest. A receipt system might be used when making deposits, allowing members to cash in their receipts for grain later in the season, but this requires strong record-keeping skills.

CONCLUSIONS

Although the concept of community cereal banks in terms of improving food security of vulnerable communities is clearly appealing to many agencies, in reality, sustainability is a huge problem, as the work by Lawrence Kent highlighted during the CRS 1998 workshop clearly showed. Documentation on cereal banks is not easily available, making it difficult to get accurate figures of the investment in cereal banks, but it has certainly been significant in the Sahel region. However, as soon as external support ceases, most seem to become bankrupt.

The 1998 workshop did not decide on a formal policy conclusion with regard to cereal banks despite all the failings of cereal banks discussed during the workshop, but it did recommend that resources be shifted out of cereal banks into other community projects that might have more sustainable impacts. After observing the unsustainability of cereal banks in Niger in the early 1990s, GTZ switched its funding from the creation of cereal banks to the development of credit unions (CRS 1998). One former supervisor of CRS cereal banks in Ghana termed cereal banks as effective "slow release mechanisms for food aid" but not sustainable institutions. Inventory credit schemes appear to be one form of successor, but ensuring that they benefit the poorer members of the community is challenging. Inventory credit schemes are discussed elsewhere in this review.

The reasons for the failure of most cereal banks were summarized as follows:

1. Insufficient understanding that net margins are thin—there's little room for error in trading;
2. Cereal banks frequently make management errors—inexperience, slow collective decision making, and social pressures lead to poor decisions in terms of timing and pricing of purchases and sales;
3. The managers of cereal banks are managing collective goods and not their own private affairs; hence,

there is little incentive for cost minimization or efficient management;

4. Speculative storage is less profitable and more risky than most people assumed;
5. Grain that is loaned out by cereal banks is frequently not paid back;
6. Cereal banks often suffer from corruption and other abuses of the cash box;
7. Support agents can become predators, stealing the money of the cereal banks that they are supposed to be helping (CRS 1998).

The cereal banks that do survive tend to be those that function most like private traders and help their members the

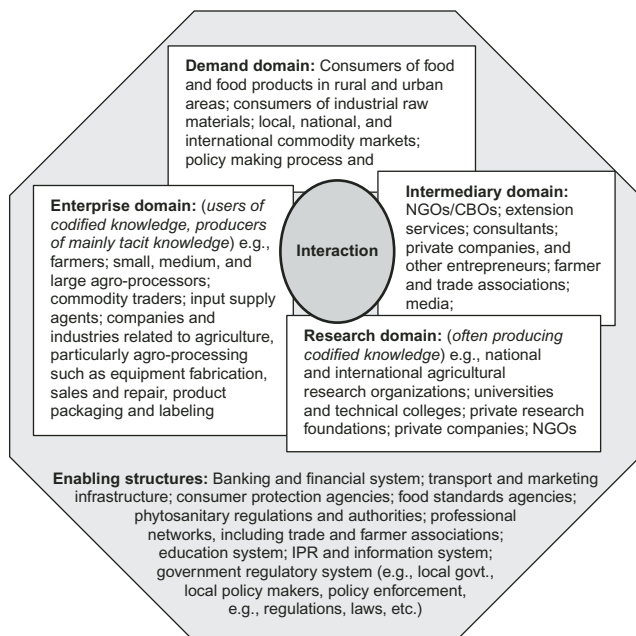
least; some of these banks actually drove private traders out of business (Berg and Kent 1991; Aker 2008). It is obviously not an efficient use of significant development resources to set up unsustainable cereal banks that do not help their members in the long term. Efficient grain trading does not usually occur when done collectively and as a result of external initiatives. In an emergency relief context, grain cereal banks can play a temporary role supplying food on favorable terms; however, this is on an unsustainable relief basis only and still requires significant resource investment. Social protection programs such as cash or food for work and conditional or unconditional targeted cash transfers are likely to be more effective instead.

Annex 6. VIEWING POSTHARVEST INNOVATION SYSTEMS

Building on the World Bank (2006) study, a general analytical framework for the innovation systems concept would include the following four elements: (1) key public and private actors and their roles, (2) the actors' attitudes and practices, (3) the effects and characteristics of patterns of interaction, and (4) the enabling environment for innovation.

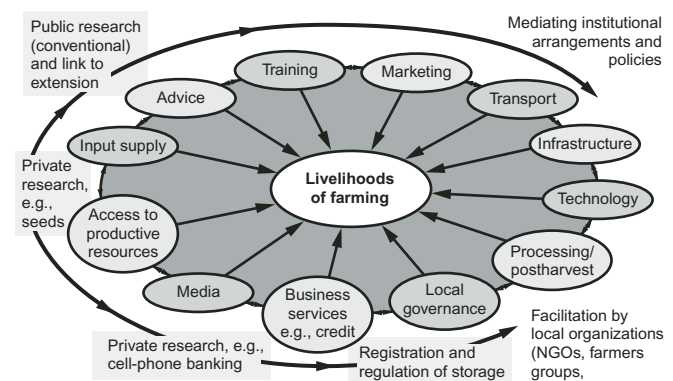
A current study on climate change and postharvest agriculture (Stathers et al. (forthcoming)), developed the following diagram representing the postharvest agricultural innovation system (figure A6.1). From the farmer's perspective, this innovation system might look more like the diagram shown in figure A6.2.

FIGURE A6.1. A postharvest agricultural innovation system



Source: Stathers et al. (forthcoming).

FIGURE A6.2. A postharvest agricultural innovation system from the farmer's perspective



Source: Adapted from Goldman (2005) and Mvumi et al. (2008).

Annex 7. PRACTICAL EXPERIENCES OF USING RISK MANAGEMENT INSTRUMENTS

GHANA EXPERIENCE (ANNEX 2, PROJECT 1)

The inventory credit approach supported by TechnoServe in Ghana involved maize farmers putting their grain up as collateral to secure loans through their local cooperatives shortly after harvest. The amount of the loan was approximately 75–80 percent of the value of the collateral they deposited. Later in the year, the farmers had the choice of repaying their loans with interest and recovering their collateral or having their cooperative sell their collateral, deduct the outstanding amount of the loans, and refund any remainder to the farmers. TechnoServe did not provide the cooperatives with a revolving fund, but instead facilitated a relationship between the cooperative and commercial banks. High intra-annual price variation in Ghana enabled farmers to increase their revenues. While the farmers' groups participating benefited from the inventory credit system, the scheme has been problematic because the scale of operation was too small. Farmers typically accumulate about 50 tons. The existing financial institutions have little incentive to operate at this scale, with the result that TechnoServe was responsible for the operations of the system, thus limiting its sustainability without subsidy. It was therefore discontinued in 2005. Although the system is worthwhile, it can only really be implemented if it is accepted that some form of subsidy is necessary. It is considered that a pilot scheme of 5–7 years, where gains made using inventory credit are forced into a credit-saving scheme, would stand a much greater chance of success.

NIGER EXPERIENCE (ANNEX 2, PROJECT 2)

In Niger there has been an inventory credit system since 1999 in which the smallholders, through their POs, have stored their products until the lean season and secured loans from MFIs that enable them to undertake income-generating activities, especially to invest in technologies to increase production, such as the administration of fertilizer by a system of microdosing. Subsequently, they can sell the stock deposited or retain it for family consumption during the lean period

when prices are generally high. The system proved popular but fell into decline in 2003–04 due to problems with mutual MFIs who had a poor understanding of inventory credit. This was corrected by the appointment of direct-credit MFIs that were supported by international investment funds and commercial loans from trade banks.

Overall, inventory credit in Niger is regarded as a success. In the southern parts of the country, inventory credit seems to be a more powerful tool than cereal banks in promoting food security during the lean season. In addition, it appears that inventory credit is a good tool to encourage cooperation between smallholders—although, paradoxically, an important attraction of the approach rests on the fact that the food is stored in the name of the individual, allowing more direct appropriation of any gains.

MADAGASCAR EXPERIENCE

The “Village Community Granaries” started in the early 1990s and involve smallholders producing rice and other agricultural commodities for home and local consumption. The scheme has taken off well, and in 2008, around 19,800 tons of paddy were stored (Coulter 2009). By enabling farmers to store longer, it has provided them with a financial surplus equivalent to a 50 percent increase in paddy yield and has contributed to the stabilization of prices regionally (Fraslin 2005). There was financial support from village-based credit unions backed by several donors, but key to this achievement was the members' subscription of substantial equity capital, which commits them to the enterprise and helped in obtaining soft-loan funding from the public treasury (Fraslin 2004). The network was expected to break even by 2006. Members are provided with inventory credit along with seasonal production credit, leasing, and other credit products, and there is also a more modest savings facility. There is a complete supervisory structure for ensuring correct storage protocols and the integrity of the inventory credit system.

This experience shows that it is possible to organize sound, village-based inventory credit systems within a strong movement of rural credit unions or rural banks. However, it has to be recognized that most African countries do not have such large or robust member-owned rural savings and credit organizations, and this makes it more difficult to achieve the same result.

WAREHOUSE RECEIPTS ZAMBIA (ANNEX 2, PROJECT 3)

A successful outcome for WRS in Zambia is favored by significant production by large-scale commercial farmers; it established inventory credit facilities under collateral management agreements run by international inspection companies. Compared with its neighbors (Zimbabwe and Malawi), Zambia enjoys relative freedom of trade and movement of currency, and the level of seasonal price variability in the leading crop (maize) is very high. But the challenges faced in introducing WRS in Zambia include disabling elements in the policy environment, legal issues, engendering confidence among bankers, scale economies, and ensuring smallholder participation. Governments often resort to ad-hoc interventions, which can potentially undermine inventory credit programs on food-security grounds. This phenomenon hampered two schemes in Ghana during the 1990s. Building stakeholder consensus and policy coherence has emerged as critical to reducing, though not eliminating, ad-hoc interventions. In the case of Zambia, this approach enabled local stakeholders to effectively counter pre-electoral policy reversals and prevent the project from being derailed.

In 2003, a national network of privately managed warehouses was authorized to issue transferable warehouse receipts, backed up by a thorough certification and inspection system. The WRS was regulated by a nongovernmental certification and inspection agency—ZACA Ltd. The initial indications from ZACA were positive, and by the 2004–05 season, available certified storage space rose from 8,000 to 105,000 tons, and about 66,000 tons of maize were deposited in the certified warehouses. Commercial farmers had predominated among the “early adopters” of this system, but smallholders were getting involved, depositing around 5,800 tons of grain. However, the performance of the system declined thereafter. It was replaced by ZAMACE in October 2007, which, to increase the economies of scale, focused on the commercial grain sector. This commercial orientation resulted in lower service costs, which increased the opportunities for the participation of smallholders.

Warehouse Receipts Uganda (annex 2, project 4)

Uganda has had a functioning WRS since 2009, regulated by the Uganda Commodity Exchange (UCE). The minimum deposit of 10 tons of maize, coffee, cotton, or beans may be placed with one of three licensed warehouse operators—provided it meets stated quality grades—in return for transferable warehouse receipts issued through an electronic system based in South Africa. Housing Finance Bank finances the warehouse receipts to 60 percent of the value of the commodity deposited. The WRS is nascent and needs more warehouse operators to be certified before the planned improvements in the grain market can be delivered. There are two barriers to increasing the number of operators: the relatively small number of warehouse operators in Uganda and liquidity requirements for licensing. A further issue is the incentive for depositors to market their grain through the WRS. This has been boosted because the UN WFP has adopted more flexible procurement modalities through its P4P project (annex 2, project 7). WFP will now purchase warehouse receipts, and this has the advantage of enabling them to buy from stock at a predetermined quality. However, WFP’s role is to facilitate transactions with the ultimate goal of encouraging regional grain traders to purchase the Uganda maize surplus.

Warehouse Receipts Kenya (annex 2, project 5)

In April 2008, a WRS was launched, regulated by the EAGC with credit based on grain as collateral, from the Equity Bank. Only maize is accepted, and deposits must be 100 tons or more. The NCPB leases out storage facilities, EAGC certifies them, and Lesiolo Grain Handlers provides postharvest grain services. At the time of launch, one warehouse complex received 1,000 tons of maize from 10 individual farmers and was encouraging smallholders to form groups and submit their harvest in bulk. Six of the 10 farmers applied and received loans from Equity Bank (totaling about US\$130,000), using the warehouse receipts as collateral. In the following two seasons, the combination of low yields and favorable weather encouraged sun drying of maize and storage in houses so that farmers could bargain for higher producer prices from the government. To appease farmers, the government instituted price controls, increasing the price of 90 kg of maize from KSh1,300 to a high of KSh2,300, which made the WRS offer unattractive. As a result, WRS operation has been hampered by government price intervention. The government’s intention to restructure both the NCPB and the grain trading system may give an opportunity to expand the WRS, especially to Eldoret, Kitale, and the South Rift regions. Lack of warehousing facilities may present difficulties, although since launch, Lesiolo Grain Handlers has been joined by Export Trading, which has warehouses in Eldoret and Kitale.



A G R I C U L T U R A L A N D R U R A L D E V E L O P M E N T



THE WORLD BANK

Agriculture and Rural Development (ARD)
1818 H Street, NW
Washington, D.C. 20433 USA
Telephone: 202-477-1000
Internet: www.worldbank.org/ard

This is a joint publication with:



**Natural
Resources
Institute**