Food and Agriculture Organization of the United Nations

Food loss analysis: causes and solutions

Case study on the maize value chain in the Federal Democratic Republic of Ethiopia

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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Foreword

Widescale global food losses and waste affect the sustainability and efficacy of food and nutrition systems. Currently, high loss estimates in developing countries are linked to food supply chain failures but insufficient data limit the scale and scope of food loss measurements.

While numerous studies have been undertaken to quantify food losses at the national level, information regarding the critical loss points, or areas where food loss in a specific food supply chain is most prevalent, is often unclear. Compounding the challenge, the underlying reasons for loss-inducing food supply chain failures also require further examination.

To improve global, regional and local knowledge about the underlying reasons for food loss, as well as to assess where critical loss points occur, FAO undertook a series of case studies involving

numerous food supply chains in developing countries. Utilizing a defined food loss and waste analysis framework, the Organization and its partners identified nationally-important food products and commissioned local-level studies of the losses in these chains. The findings of the study will be used to develop technically, economically, environmentally and socially feasible solutions to reduce food losses. These solutions will be developed both in the chains examined, as well as in similar chains in other countries, with due considerations for economic parity, agro-ecology and social conditions.

Maize is one of the most widely grown and consumed grains in Ethiopia and is critical for incomes and food and nutrition security across the country. Close to nine million smallholder farmers produce the crop and between 70 to 80 percent of the maize is consumed within producer households, the surplus marketed. The findings documented in this publication provide an evidence base for the development of interventions to address losses in the maize subsector. A reduction in maize losses could generate significant benefits across the food supply chain, including increased earnings and food availability in markets.

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Abbreviations and acronyms

ADLI	Agriculture Development-Led Industrialization
AGP	Agriculture Growth Program
ATA	Agricultural Transformation Agency
BDS	Business Development Services
CIMMYT	International Maize and Wheat Improvement Centre
CLP	Critical Loss Point
CRGE	Climate Resilient Green Economy (Ethiopia)
CSA	Central Statistics Agency
CWRS	Community Warehouse Receipt System
ECEA	Ethiopian Commodity Exchange Authority
ECX	Ethiopian Commodity Exchange
EGTE	Ethiopian Grain Trade Enterprise
EIAR	Ethiopian Institute of Agricultural Research
EPA	Environmental Protection Authority (Ethiopia)
ESA	Ethiopia Standards Agency
ESE	Ethiopian Seed Enterprise
ETB	Ethiopian birr
FAO	Food and Agricultural Organization of the United Nations
FSC	Food Supply Chain
FTC	Farmers Training Centre
GHG	Greenhouse Gas
GTP	Growth and Transformation Plan
Ha	Hectare
HLI	Higher Learning Institution
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
Kg	Kilogram
Km	Kilometre
LLP	Low Loss Point
MCH	Multiple Crop Harvester
MoANR	Ministry of Agriculture and Natural Resource
MoI	Ministry of Industry
MoFED	Ministry of Finance and Economic Development
MoT	Ministry of Trade
NARS	National Agricultural Research System

NGO	Non-Governmental Organization
PASDEP	Program for Accelerated and Sustainable Development to End Poverty
PFL	Prevention of Food Losses
PHFL	Post-harvest Food Loss
PHL	Post-harvest Loss
PICS	Purdue Improved Crop Storage
PSE	Public Seed Enterprise
RARI	Regional Agricultural Research Institutes
RATES	Centre for Regional Agricultural Trade Expansion Support
RSE	Regional Seed Enterprise
SD	Standard Deviation
SDC	Swiss Agency for Development and Cooperation
SG-2000	Sasakawa Global 2000
SHF	Smallholder Farmers
SNNP	Southern Nations, Nationalities and Peoples
USD	United States Dollar
UNJP	United Nations Joint Project
USDA	United States Development Agency
WFP	World Food Programme

Introduction to the case studies

About 1.3 billion tonnes of food losses and waste are estimated to occur every year globally (FAO, 2011), affecting the efficiency and sustainability of global food systems and nutrition. Accurate estimates of the magnitude of losses and waste are still lacking especially in developing countries where most smallholder farmers produce and consume grains and pulses as a staple food; nevertheless, the high loss estimates suggest that food losses are significant and have a negative impact on food and nutrition security.

In light of the above, the Food and Agriculture Organization of the United Nations (FAO) and its partners launched the Global Initiative on Food Losses and Waste, to reduce food losses and waste using various approaches including awareness-raising and developing a methodology to research post-harvest losses among other initiatives. Multiple partners have supported efforts at the national and regional levels through various projects including the Project on Food Loss Reduction through partnerships and evidence-based interventions, also known as the United Nations Joint Project (UNJP). The UNJP, which is funded by the Government of Ireland, is a collaborative initiative on food loss reduction between FAO and the International Fund for Agricultural Development (IFAD).

Food losses refer to the decrease in edible food mass throughout the different segments of the food supply chains: production, post-harvest handling, agroprocessing, distribution (wholesale and retail) and consumption. Food losses and their prevention have an impact on the environment and climate change, food security and livelihoods for poor people and economic development. The exact causes of food losses vary throughout the world and are very much dependent on the specific conditions and local situation in a given country, region or production area.

Literature reviews, statistical data and stakeholder interviews have been used in studies to assess the quantities of food lost at the various stages of food handling in various countries.

These studies have established some certainties and existing knowledge gaps. Certainties include quantitative estimations of food losses and the major causes of food losses. What is not clear are the kinds of losses that are important for specific food chains, the impact of suggested solutions, and which are feasible economically, environmentally and socially.

It is clear that food loss reduction will greatly benefit all actors in the food supply chains, ensure food security for poor people, improve resilience to climate change and increase the efficiency of how natural resources are used. The solution to food loss should not be more expensive than the value of the food lost, nor should it cause any negative impact or risk to consumer health. Also it should not place more of a burden on the environment or increase greenhouse gas (GHG) emissions. Instead, it should make more food available to the people that need it most, and should be socially and culturally acceptable.

Therefore, the Save Food Initiative has designed the 'food supply chain' case studies for the most important food subsectors in developing countries for the generation of data relating to the different causes of food loss. Solutions for food losses are analysed for their feasibility. Up to now, no standardized methodology has been used to conduct loss assessments. This has made it very difficult to compare results between countries and regions. Using a standardized methodology across the participating countries is very useful in terms of being able to compare results and sharing information.

A case study is just a one-moment recording of what is happening in a specific food supply chain in a specific season and in a specific location; in another season or in a different location the situation can be very different again. Consequently, the Save Food Initiative considered it important that it undertakes many case studies in different locations so that the various study results would provide significant trends and solutions. Further, the strategy aimed to use the results of the case studies to target opportunities for investment programmes and interventions, during formulation a wider geographical scope and the seasonality will be analysed.

The assessment of post-harvest losses along maize supply chains used the methodology developed by FAO under the Save Food initiative and adapted it to the specific conditions and local context. The Government of Ethiopia has identified the maize subsector as a priority commodity for the reduction of post-harvest losses. In this case study, two supply chains (one per commodity) were selected for further analysis. They involve smallholder farmers, cooperatives, transporters, traders, millers, warehouse managers of cooperatives and daily labourers.

The main objectives of this study were to:

- obtain a clear view of the weak points in the maize supply chain where food losses occur;
- evaluate quantitative and qualitative losses;
- analyse their main causes; and
- identify key interventions to reduce food losses and improve the efficiency of the food supply chain (FSC), eventually leading to concrete proposals to implement a food loss reduction programme.

An effective food loss assessment in a supply chain involves the collection of data and its analysis. Quantitative and qualitative field methods were used for the assessment. Subsequently, the results and conclusions of the assessment were used to formulate solutions and strategies to control food loss.

Through the formulation of food-loss reduction strategies, the project adopts a holistic approach based on the entire supply chain, recognizing the strong role of multiple actors, including the role of institutional structures and the policy environment.

Given the magnitude of food losses, making profitable investments in reducing losses and improving the efficiency of the food supply chain could help bring down the cost of food to the consumer, increase access to food, while improving economic returns to farmers and other actors in the value chain.

> *The objective of this study is to identify the main causes of food losses in the selected food supply chains, and provide an analysis of the various options available for reducing food losses including their technical and economic feasibility, social acceptability and environmental impact, leading to concrete proposals for the implementation of a food loss reduction programme. Although attempts have been made to quantify actual losses after an activity along a supply chain, the final loss figures used are mostly estimates. Where there is need to use accurate loss figures, for instance in tracking achievements in loss reduction efforts, this requires a more detailed statistical analysis, which is beyond the scope of this study.*

IMPLEMENTATION METHODOLOGY OF FIELD STUDIES

The assessment of post-harvest losses along maize supply chains used the methodology developed by the Save Food Initiative. The supply chain food-loss assessment involves the collection of data and its analysis, using qualitative and quantitative field methods. Subsequently, the results and conclusions of the assessment are used to formulate solutions to food losses. The methodology used in the 'food supply chain' case studies is described below.

Selection of countries and subsectors

In order to make it possible to work with partners in the field, existing and ongoing programmes were used to select countries and subsectors for the study cases.

Subsectors were chosen from the important food commodities in Ethiopia, which included cereals; roots and tubers; fruits and vegetables; oilseeds and pulses; fish and seafood; and animal products (meat, milk, eggs, etc.).

Identification of Consultants

Three national consultants conducted the fieldwork including a subsector specialist, who could be an actor in the food supply chain, an agricultural economist and a sociologist.

Selection of Food Supply Chains

The criteria used to rank the main supply chains were importance in terms of economic impact and food security and contribution to national development objectives such as employment, poverty reduction and the generation of foreign exchange. Based on the information obtained, one or two FSCs in the subsector were selected for in-depth survey and sampling.

The basic criteria for selection of the FSCs were:

- based on smallholder producers;
- significant scale of food production;
- preferably including agroprocessing and urban market; and
- if possible, included in an ongoing support programme for the subsector

Uniform methodology

The methodology of the case studies was uniform for all countries, so that the results would be comparable and extrapolation would be possible. It is comprised of four ('S') elements:

- *Preliminary food losses (Screening)* are screened based on secondary data, documentation and reports, and expert consultations without travel to the field.
- *Survey Food Loss Assessment (Survey)* uses different questionnaires for producers, processors or handlers or sellers for example warehouse managers, distributors, wholesalers, and retailers and other knowledgeable people in the supply chain being assessed, complemented by ample and accurate observations and measurements.
- *Load Tracking and Sampling Assessment (Sampling)* is useful for quantitative and qualitative analyses at any step in the supply chain.
- *Monitoring and Solution Finding (Synthesis)* is used to develop an intervention programme for food losses, based on the previous assessment methods.

The consultants physically follow the product and the process from production site to final retail outlet, make direct observations and measurements and discuss the causes and solutions of food losses with supply chain actors. Finally, the consultants draft a proposal for a food-loss reduction strategy or plan.

Stakeholder validation

Stakeholders from the public and private sectors meet in a one-day workshop to discuss and endorse the study results and the proposed food-loss reduction strategy. A concept for a programme to finalize and implement the food-loss reduction strategy or plan is prepared.

Methodology adapted for maize

Researchers selected maize for this investigation because of its economic and social importance, production and cultivation areas, and marketability through multiple paths and long supply chains, reaching and covering a large community. Other criteria considered included being a food and income source for a large portion of the population in both rural and urban areas, being employment opportunities for a large number of people, and the paramount contribution to foreign exchange generation and food security.

- The *screening method (desk review and consultations)* was used to gather data and information on the range of losses and some of their main causes.

Collection of secondary data was through reviewing documents of secondary sources from relevant institutions. Beside relevant published and unpublished reports, the researchers browsed websites, and bulletins to generate relevant secondary information focusing on maize production and marketing. Furthermore, from these secondary sources, data on prices, outputs, numbers of licensed maize traders, and maize marketing systems, etc. were collected.

The method was instrumental in identifying the critical and low loss points maize supply chains. It also provided some background information for implementation of the *survey* and *sampling* methods. This method helped to develop a qualitative understanding of losses and provided indicative quantitative data for the entire loss assessment. It provided an overview of the food supply chain.

- The *survey method* employed a questionnaire that was given to small farmers and the 'Key Informant Interview – KII', which was a qualitative instrument developed for other actors and stakeholders involved in the FSC (e.g. traders, processors, etc.). The sources of primary data were smallholder farmers who were randomly selected from one rural *kebele*, the farmers' service cooperative association (union) and traders at different levels, ranging from farmer traders to regional level wholesalers.

The case study took place in December 2015 in Burka Golu *Kebele*, Deder *Woreda*, in Oromia regional state of Ethiopia. The following methods were used to collect data:

- Interviews, used a pre-tested semi-structured interview scheduled questionnaire. The formal survey was based on 25 farmers in the *kebele*. The *kebele* was part of the IFAD project for the Participatory Small-scale Irrigation Development Programme (PASDIP).
- Qualitative data was also gathered during focus group discussions with key informants. The checklist–based qualitative survey relied heavily on the internal assessment of the actors (traders, processors, etc.) in the chain. 37 key informants were interviewed.
- Observations of FSC activities and stakeholders complemented the survey. Post-harvest operations, and percentages of losses at each level of the supply chain helped generate primary data. Data generated from the questionnaires was used to compute the percentages of losses (kg/100 kg of grain) along the supply chain. The monetary values were based on the price of 1 kg of maize grain (USD 0.2524).
- The *load tracking and sampling method* was employed to evaluate the quantitative and qualitative maize losses at specific steps in the supply chain and to identify the respective causes of these losses. Sampling was at the storage stage, as the *screening* and the *survey* revealed this stage was a critical loss point (CLP). Even though maize shelling in surplus maize production areas was considered to be a CLP, load tracking was not conducted in the study area since shelling is done by hand, resulting in low losses.

The researchers selected three villages in the *kebele* for the study. Sampling was in two stages in each village in order to measure qualitative and quantitative losses. Three units (30 percent) were used from the harvest produced by nine farmers (three farmers were selected in each village) at the first sampling stage. For the second stage sampling, one random sample of 1 kg was used from each selected unit as a measurable unit, thus making a total of nine sampling units for the three villages.

This process was carried out before and after each of the two steps studied (threshing and storage).

Samples were analysed at the laboratory. The method of *load tracking and sampling* was employed at the storage stage, with quantitative and qualitative losses of maize measured before and after five weeks of storage.

POLICY-MAKING AND NATIONAL STRATEGIES

Before 2000, post-harvest grain management issues were given limited policy attention, compared to that given to increasing agricultural production and productivity. Since 1993, Ethiopia has been following an overarching agriculture development policy called *Agriculture Development-Led Industrialization (ADLI)* in response to challenges related to prevailing food security and agricultural productivity. Since the adoption of ADLI, the Government of Ethiopia has implemented a number of national economic growth and development plans, which are described below.

The *Programme for Accelerated and Sustainable Development to End Poverty (PASDEP, 2004/5-2009/10)* stressed the need to promote post-harvest technologies to improve the performance of market chains through training, development and dissemination of post-harvest loss reduction technologies.

Ethiopia's Growth and Transformation Plan (GTP, 2010/11-2014/15) briefly touched on the issue of product storage in the context of promoting market access (MoFED, 2010)1. The corresponding five-year agriculture sector plan only mentioned improving storage infrastructure, without providing any details of an implementation strategy, or an action plan that specifies targets for the expected outputs of the sector.

The *Agriculture Growth Programme (AGP)*, as the main government programme addresses agricultural growth in Ethiopia, and is focused on attaining reduced post-harvest losses. In line with this programme, the Agricultural Transformation Agency, in collaboration with the Ministry of Agriculture, multi-lateral agencies, non-governmental organizations (NGOs) and the donor community are aggressively working to enhance the value chains of selected crops. This value chain approach aims to ensure

[1] MoFED. 2010. Ministry of Finance and Economic Development (MoFED). Growth and Transformation Plan 2010/11-2014/15, Addis Ababa, Ethiopia.

that all components of the grain sector are addressed in a comprehensive and coordinated manner, considering:

- research and technology development;
- access to inputs;
- on-farm production;
- post-harvest processing and storage; and
- trade and marketing.

With regard to post-harvest handling of grain crops, the focus intervention areas are:

- to increase access to post-harvest processing equipment and technologies;
- raise the awareness of farmers and facilitate access to effective on-farm storage; and
- increase farmers' access to community-level storage facilities with skilled personnel.

The current *Agriculture Sector Growth and Transformation Plan II (2015-2020)* aims to reduce the post-harvest losses of major crops from 25 to 5 percent by aspects of agricultural mechanization and post-harvest losses including:

- enhancing harvesting, threshing and shelling operations using mechanical technologies and
- improving transportation and storage of agricultural produce using modern and mechanical technologies.

In the Growth and Transformation Plan (GTP) II, agricultural extension will address the needs of women farmers through gender-sensitive approaches. Focus areas of implementation include awareness creation, encouragement of the participation of women and rural youth in agricultural extension, and provision of training to enable development agents to support women and rural youths in agricultural activities.

Although the attention given to post-harvest loss issues in these strategic plans vary, the reduction of post-harvest losses has recently received closer attention. In response to GTP II, the Ethiopian Institute of Agricultural Research (EIAR) has given special emphasis to post-harvest loss reduction and developed a separate strategy for post-harvest research. Strict implementation of these strategies with the synergetic effort of various actors will bring about significant differences in the reduction of post-harvest losses.

Identifying solutions to food losses could add value to the Ethiopia Climate Resilient Green Economy (CRGE) strategy (EPA, 2011[2]). Reduction of food losses will contribute to the realization of the first pillar of the CRGE, which is 'Improving crop and livestock production practices to increase food yields, hence food security and farmer income, while reducing emissions'. Ensuring food security and improving farmers' income would indirectly impact the remaining three pillars: i.e. reducing deforestation, improving access to renewable energy and energy efficient technologies.

Food safety and quality policies

The Ethiopian Standards Agency (ESA) has developed a standard that specifies requirements for grading dry dent maize, or shelled flint maize, or their hybrids ready for human consumption. The standard specifies four grades rated against minimum requirements for test mass; maximum requirements for impurities such as broken kernel, foreign matter, blemished grain, immature and other grains (Table A). However, the implementation of the standards is minimal in market transactions.

RELEVANT INSTITUTIONS AND THEIR ROLES

The Ministry of Agriculture and Natural Resources (MoANR) and the Regional Bureaus of Agriculture (RBoAs) are the major institutions for food loss management and are responsible for the development of agricultural policies. Besides their mandate for leading agricultural development activities, they have an organizational structure down to the grassroots level that enables the Ministry to disseminate post-harvest loss reduction technologies. This makes it the most relevant institution having a major stake in the improvement of agricultural production and food loss reduction.

[2] EPA (Environmental Protection Authority). 2011. The path to sustainable development, Ethiopia's Climate-Resilient Green Economy Strategy. Federal Democratic Republic of Ethiopia.

TABLE A
Grades of maize grain

S.N	Grading characteristics	Grades			
		1	2	3	4
1	Test mass kg/hl, min	71.0	68.0	66.0	64.0
	Impurities	Maximum limit percent by mass			
2	Broken kernels	2.0	3.0	4.0	5.0
3	Foreign matter	0.5	1.0	1.5	2.0
4	Blemished grain, including	3.0	5.0	7.0	10.0
	Stained, discoloured, sprouted, frost damaged, diseased, insects damaged, and of which:				
	Diseased grain	0.5	0.5	0.5	0.5
	Insect damaged grain	0.5	1.5	2.0	3.0
5	Immature grains	1.0	2.0	4.0	6.0
6	Other grains	0.5	0.5	1.0	1.5
7	Contrasting classes	1.0	2.0	4.0	6.0

Source: ESA. 2001b. *Ethiopian Standard, Maize (Corn)-specification*, ES 679:2001. First edition. Reaffirmed: 2012.

The National Agricultural Research System (NARS) incorporates the EIAR, the Regional Agricultural Research Institutes (RARIs) and Higher Learning Institutions (HLIs) with agricultural faculties. Particularly, EIAR and RARIs have the mandate to generate improved post-harvest technologies, information and knowledge. HLIs are primarily responsible for the production of skilled post-harvest professionals who can take part in research and development programmes and undertake relevant food loss research. NARS also plays an important role in the dissemination of post-harvest technology through demonstrations.

The Ministry of Trade (MoT) has a mandate to manage the licensing and registration of traders, the MoT works on stabilizing local grain marketing and improving the country's competitiveness in foreign markets. It does this through the formulation and implementation of relevant and appropriate trade policies and strategies, and collection, analysis and dissemination of trade-related information to relevant members of the business community.

The Ministry of Industry (MoI) has a mandate to develop agroprocessing industries by creating conducive conditions to encourage investment in the sector. The Ministry is also involved in generating agroprocessing industrial project ideas and linking them to relevant stakeholders and attracting joint ventures from abroad. The MoI supports agroprocessors in line with the country's industrial development strategy.

The Ethiopian Standards Agency (ESA) mainly focuses on standard formulation, training and technical support, organizing and disseminating standards, and the formulation of conformity assessment procedures and handles technical regulation for the customers.

Farmers' Associations and Cooperatives play important roles in the development of the grain sector through providing farm inputs such as fertilizers, seeds and pre and post-harvest pesticides, facilitation of market linkages and credit system to farmers.

The Private Sector's increased investment and involvement contributes to the reduction of post-harvest losses, particularly through participation in production and distribution of improved harvesting, transportation, and threshing or shelling, cleaning, storage and preservation technologies. The private sector can also supply the necessary consumable inputs to the post-harvest value chains (e.g. Shayashone Agribusiness Consultant).

Non-Governmental Organizations (NGOs) have a critical role in post-harvest loss reduction. NGOs help in building the capacity of stakeholders, especially smallholder producers through provision of technical training and infrastructure and dissemination of improved post-harvest technologies (e.g. Sasakawa Global (SG)-2000).

Public Seed Enterprises (PSEs) include the Ethiopian Seed Enterprise (ESE) and Regional Seed Enterprises (RSEs) in Amhara, Oromia, and SNNP regions. PSEs are responsible for implementing government targets to produce sufficient quantities of high-yielding improved seed for key crops, while also functioning as independent profitable businesses.

The Agricultural Transformation Agency (ATA) continues to provide implementation support in the form of continued problem solving, resource mobilization, project management, and coordination at various levels of the Ethiopian agriculture system.

Executive Summary

Maize (*Zea mays* L.) is one of the main food and feed crops in Ethiopia and worldwide. It continues to be a significant contributor to the economic and social development of the country. Maize mostly grows at mid or lower altitudes and in sub-humid agro-ecologies along the western, southwestern, and eastern borders.

The crop is indispensable to the livelihoods of Ethiopian smallholders and approximately 8.7 million smallholder farmers grow the crop. As an important staple food source as well as a cash crop, maize provides a significant contribution to daily calories for consumers as well as income for producers and traders. Although the proportion may vary between individual farmers, generally 70 to 80 percent of the crop production is for the farmers' own use, while the remaining is for sale.

The maize field activities were carried out in Burka Golu *Kebele,* Deder *Woreda* District, Oromia Region. The primary data sources were smallholder farmers (SHF) who were randomly selected from the study *kebeles*, representatives of the farmers' service cooperative associations (unions) and traders at different levels, ranging from farmer traders to regional level wholesalers. Secondary data sources were various reports and documents.

Most post-harvest operations are traditional, time-consuming and labour-intensive, and they have been used for centuries in the same way, with little or no improvement. Farmers harvest maize manually by cutting the corn off the stalk with sickles before threshing it using sticks or hands.

Traditional and improved *gotera*[3] as well as polyethylene sacks are widely used for storage in the region. Crops are mostly transported by labourers or pack animals from the fields to stacking or threshing sites, and from the threshing floors to storage facilities. Transportation is an important marketing function, which enables producers in surplus producing areas to obtain better market prices, and consumers in deficit areas to get reduced marketing prices. As a result of the poor local market infrastructure, most farmers have to transport their produce 30 km to a major market within a *woreda*, using pack animals, human labour or when possible, vehicles.

Post-harvest food losses are economically significant in Ethiopia for a broad range of commodities such as maize and teff, resulting in a substantial negative impact on food security and import substitution. The causes of losses are many and varied. They include moisture levels; harvesting, threshing and storage methods drying techniques and attacks by insects, rats and other pests. However, the main causes for maize losses include poor threshing, storage and handling facilities and practices.

In the absence of appropriate and feasible technologies, traditional and uneducated post-harvest operations (handling, processing and distribution) are the major factors leading to post-harvest losses. There is a lack of awareness among farmers, agricultural personnel, policy-makers and other stakeholders of the negative impacts of post-harvest losses and how they hinder reduction of post-harvest food losses at the farmers' level.

Promotion of the post-harvest sector is also constrained by an inadequate policy framework, lack of technical and technological support for farmers, and financial constraints faced by post-harvest technology generators, private distributors and smallholders. Moreover, areas of concern in the sector's development include lack of focused training and education about the country's post-harvest problems and remedies, poor linkages among education, research and extension services and absence of institutions responsible for coordinating, facilitating operational and policy research and activities.

To address these challenges, the study recommends the introduction and promotion of proven and affordable post-harvest technologies such as metal silos, hermetic bags, multiple crop harvesters (MCH) mechanical threshers, shellers, and pre-storage protectants. These technologies have been proven to provide significant benefits to farmers based on productivity gains, quality improvement and reduced labour costs.

[3] *Gotera* is a structure constructed from wood and sticks fixed together in cylindrical or rectangular form or splits of bamboo woven into a big basket and plastered with mud and straw.

These technologies must be popularized through awareness-raising about the costs and impacts of post-harvest losses (PHL), dissemination of training and knowledge and increased financial access to machinery for farmers and small enterprises. Strengthening institutional support and post-harvest research would encourage the adoption of modern technologies and enhance post-harvest loss reduction efforts.

Chapter 1
Introduction and background

STATUS AND IMPORTANCE OF THE MAIZE SUBSECTOR

Maize (*Zea mays* L.) is one of the main food and feed crops in Ethiopia and worldwide. It continues to be a significant contributor to the economic and social development of the country. Maize is cultivated mostly at mid to lower altitude and sub-humid agro-ecologies along the country's western, southwestern and eastern borders (Berhane and Bantayehu, 1989; Kebede *et al.* 1993).

As the crop is grown by a large number of smallholders (8.7 million), it is critical to small-

TABLE 1.1
National production information in the maize subsector

	Annual production (tonne/year)	Cultivated area (ha)	Average yield (tonne/ha)
Product (maize)	7.2 million	2.1 million	3.4
Average annual growth over the last 10 years (percent)	9.6	4.3	5.9
Average cost of production (USD/tonne)			
	On-farm consumption	**Marketed**	
Percentage of production	80	20	
	Volume (tonne/year)	Value (USD/year)	
Market product #1 (Grain)	1 447 000	289 398 200	
Market product #2 (Stalk)	NA*	NA*	
Item	**Number women**	**Number men**	**Total**
Producers	NA	NA	8.7 million
Traders in Deder Woreda	36	156	192
Processors # 1 ** (milled and semi-milled products) in Deder Woreda	0	13	13
Processors #2 (starch and starch products) in Deder Woreda	0	3	3
Processors #3 (bread, cake, biscuits and injera)	1	6	7
	Small	**Medium**	**Large*** **
Level of processing operations	•		
Level of trading/wholesale		•	
Level of retail operation	•		

Source: CSA (2015) and RATES (2003)
*NA = Data not available; **Local millers who give milling service to consumers are not considered. ***Number of employees/workers: Small: <10, Medium: 10-50 and Large: >50

TABLE 1.2
Food safety management mechanisms

Controller	Control	Actual situation in the FSC		Responsible Agent
Government regulation and requirements	National food safety/quality standards	Exists and applies to the whole FSC		Quality and Standards Authority of Ethiopia
		Exists but not rigorous	x	
		None		
	Frequency of checking (None, Low, Medium, High)	Harvest	None	Ministry of Health, Ministry of Agriculture and Rural Development, Ministry of Trade and Ministry of Industry, and Quality and Standards Authority of Ethiopia
		Transport	None	
		Storage	Low	
		Process	Low	
		Market	Low	
	Obligatory registration of the food processing/ preparation unit	Exists	x	Ministry of Industry, Ministry of Trade
		None		
FSC actors - food safety management system	GHP/ GAP/ HACCP/ voluntary standards	Yes (Ethiopian standards, ES 588:2001)		
	Identification of potential hazards			

Source: secondary data

holder livelihoods in Ethiopia. It is one of the most important staple food and cash crops, providing calories for consumers and income for producers and traders. Maize is mainly cultivated for consumption. According to the Centre for Regional Agricultural Trade Expansion Support (RATES, 2003), 80 percent of the total national production is used for household consumption and seeds, while the remaining 20 percent is for sale.

Maize production in Ethiopia has shown a considerable increase over the last fifteen years with a drastic increment in recent years. Production increased from as low as 3.1 million tonnes in 2000 to over 7.2 million tonnes in 2014, which represents an increase of 130 percent (USDA, 2013; CSA, 2013; CSDA, 2014). There is, nevertheless, still great potential for increasing productivity. In addition, the use of maize for feed, e.g. for poultry, is gradually increasing, indicating the growing importance of maize over time. Table 1.1 below gives information on the features and importance of maize, while Table 1.2 shows food-safety management mechanisms in the country.

INVENTORY OF ACTIVITIES AND LESSONS LEARNED FROM PAST AND ONGOING INTERVENTIONS IN MAIZE LOSSES

There are no programmes for post-harvest activities, past or present. What are available are minor interventions by various organizations. After launching the GTP II, the Ministry of Agriculture and research organizations developed formal post-harvest programmes. Before the 1990s, the Ministry of Agriculture extension programme demonstrated improved *gotera*, with raised stands fitted with rat guards to protect the grain from rodents, they were minimally accepted by farmers. The reason for the low acceptance of the improved *gotera* is that it guards the grain only from rodents, not from storage insects, while the cost of construction is high. Farmers then have to use chemical pesticides (powders and fumigants) to control storage insect pests.

Maize shellers (about 75), and hermetic storage facilities (approximately 80 metal silos, over 15 000 PICS bags and plastic drums) were introduced by SG-2000 and other stakeholders for maize storage. Physical analysis of the samples, after six months of storage, revealed that the metal silo effectively protected the grain, while the control treatment (polypropylene sack) failed to protect stored grain from storage insect pests. Farmers also witnessed the superior performance of metal silos in the third and sixth months of storage over the control treatment. PICS bags provided effective protection of stored grain and are currently being demonstrated and distributed to farmers.

According to the key respondents from SG-2000, introduction of maize shellers and hermetic storage facilities resulted in reduced food loss, improved quality and saved farmers' time, thus gaining their approval. The uptake of maize shellers and metal silos was not expected because of their high initial cost, though a few innovative farmers purchased the shellers and created businesses providing a shelling service. Therefore, linking farmers with financial institutions is needed to help them procure the technologies with loans, thus facilitating dissemination of these technologies. Reports indicate that a shortage of spare parts and problems in transporting broken down shellers to nearby towns for repair are also factors contributing to the slow uptake of the technology.

OVERVIEW OF THE MOST IMPORTANT FOOD SUPPLY CHAINS IN THE MAIZE SECTOR

For this study, researchers considered five common FSCs in the study area of Burka Golu *Kebele* in Deder District. Researchers selected the supply chain that transacted the largest proportion of marketed maize grain. Harvesting, stacking/drying, threshing (shelling) and storage are the post-harvest activities common to all supply chains.

FSC 1 (Rural consumer supply chain), the first and shortest supply chain, is when farmers directly sell maize grain to consumers. This chain is common in the smaller towns, less in larger towns.

The steps in the chain are Harvesting → Stacking/Drying → Threshing (Shelling) → Storage → Transport → Consumers.

FSC 2 (Urban consumer informal supply chain), the second shortest supply chain is the transaction of grain from the farmers to the consumers through retailers in the rural or urban areas.

The steps in the chain are Harvesting → Stacking/Drying → Threshing (Shelling) → Storage → Transport → Retailers → Consumers.

FSC 3 (Wholesale market supply chain) involves assembly of grain from smallholder farmers by rural assemblers, which sell to *woreda*/zone traders, who then transport to urban centres and sell to wholesalers, from which retailers source grain and sell to the users or consumers.

The steps in the chain are Harvesting → Stacking/Drying → Threshing (Shelling) → Storage →Rural Assemblers → Transport → *Woreda*/Zone Traders → Transport → Wholesalers → Transport → Retailers → Consumers.

FSC 4 (Farmer group supply chain) involves smallholder farmers, multipurpose marketing cooperatives (primary coops and unions), consumer's cooperatives and users or consumers. This FSC has been developed only recently and is highly promoted by the government for its greater benefit to the consumer in terms of price, quality and traceability.

The steps in the chain are Harvesting → Stacking/Drying → Threshing (Shelling) → Storage → Transport → Primary Coops/Unions → Consumer Cooperatives → Consumers.

In FSCs 1-4, consumers use the maize grain they bought in different forms (bread, porridge, boiled grain or brew local beer, etc.).

FSC 5 (Agro-industry supply chain) involves smallholder farmers, assemblers, *woreda*/zone traders, wholesalers and EGTE (Ethiopian Grain Trade Enterprise), processors and outlets/multipurpose shops and users. This chain supplies processed flour or processed food like corn flakes through distributers, outlet or multipurpose shops.

The steps in the chain: Harvesting → Stacking/Drying → Threshing (Shelling) → Storage →Rural Assemblers → Transport → *Woreda*/Zone Traders → Wholesalers/EGTE → Processors → Outlets/Multipurpose Shops → Consumers.

Consumers in this supply chain eat the maize flour they bought as bread or porridge.

Table 1.3 gives general information on the food supply chains specific to the study area. The five common FSCs were evaluated and rated on

- their economic importance;
- generation of foreign exchange;
- contribution to national food consumption, and
- contribution to national nutrition and environmental impact.

Table 1.4 shows the evaluation and rating.

The researchers assessed the importance of the food supply chain for its actors on the following:

- smallholder production;
- income generation;
- involvement of the poor, and
- employment provision (Table 1.5).

Based on the total score of the evaluations, FSC 3 (Wholesale market supply chain), which scored the highest points, was selected for the case study.

TABLE 1.3
Food supply chains in the maize subsector

Food Supply Chains	Geographical area of production	Final product	Volume of final product (tonne/ year)	Number, age and gender of smallholder producers	Market of final product, location, buyers	Project support
1-5	Deder	Grain	1 680	1 240 (1 078 men and 162 women farmers)	Deder town	IFAD

Source: Secondary data
Note: The figures are for all maize supply chains in the study area. It is not possible to get separate data for each supply chain.

TABLE 1.4
Importance of food supply chains at the national level

Food Supply Chain	Economic Importance	Generation of foreign exchange	Contribution to national food consumption	Contribution to national nutrition	Environmental impact
1	2	NA	2	2	1
2	2	NA	3	2	1
3	3	NA	3	3	1
4	2	NA	3	2	1
5	1	NA	2	2	1

Source: Secondary data

Values in the table indicate rating scores of the FSCs (1-3 scale) where 1 represents low and 3 stands for high with respect to attributes in the table heading.

TABLE 1.5
Importance of food supply chains for the actors

Food Supply Chains	Percentage of product by smallholders	Income-generation	Involvement of the poor	Employment provision
1	1	2	3	1
2	2	3	3	1
3	3	3	3	2
4	2	2	1	2
5	1	2	1	3

Source: Secondary data
Values in the table indicate rating scores of the FSCs (1-3 scale) where 1 represents low and 3 stands for high with respect to attributes in the table heading.

PRESUMED FOOD LOSSES IN THE SELECTED FOOD SUPPLY CHAIN

The study identified each step of the FSC as a critical or low loss point in terms of its presumed quantitative and qualitative maize losses (Table 1.6).

Based on the information obtained from key responding experts and authors' experiences, shelling became the first critical loss point in the selected maize supply chain, with respect to both quantitative and qualitative types of losses. Study results to support the assumption are not available. This is because maize is shelled throughout the country using animals to trample or beating with sticks, mostly on unprotected ground or on a threshing floor plastered with animal dung, which may cause kernels to break or become contaminated with animal waste, soil and inert matter, or they may spill from the threshing floor. In the study area, bare hands are used to shell the maize as the grain is stripped from the cob.

After shelling, the next critical loss points were storage at farmer and retailer levels, as maize is stored for a relatively longer period compared to the other steps in the FSC. Maize is generally stored in traditional storage structures and polypropylene bags. In the study area, farmers keep unshelled maize hanging in the house under

TABLE 1.6
Preliminary screening of food losses in the selected food supply chain

FSC 3: Deder, Maize Grain		
Step in the Food Supply Chain	Presumed Losses	
	Quantitative (CLP or LLP)	Qualitative (CLP or LLP)
Harvesting	LLP	LLP
Stacking/Drying	LLP	LLP
Shelling/Threshing	CLP	CLP
Storage	CLP	CLP
Assembly	LLP	LLP
Transport	LLP	LLP
Trading (Woreda/Zone)	LLP	LLP
Transport	LLP	LLP
Wholesaling	LLP	LLP
Transport	LLP	LLP
Retailing	CLP	CLP
Consumption	LLP	LLP

Source: Secondary data

the roof for a long time, or store shelled grain in polypropylene bags. If the grain is not dry before storage, these traditional storage methods may become seriously damaged by insect pests, become spoiled or discoloured. The remaining steps in the FSC were low loss points because of the minimum losses expected or shorter stay in the transaction. However, considerable losses may occur during harvesting and stacking when there is untimely rain, especially in surplus production areas.

Chapter 2
The maize supply chain – situation analysis

DESCRIPTION OF THE SELECTED MAIZE FOOD SUPPLY CHAIN

FSC 3, the wholesale market supply chain, was found to score the highest value or grade for its importance, based on the different criteria evaluated (cf. previous section) and was selected for further analysis in this case study.

This case study was conducted in December 2015 in Burka Golu *Kebele* of the Deder district in Oromia regional state of Ethiopia. A *kebele* is the smallest administrative structure in the country. The *kebele* has 1 240 smallholder maize producers, 1 078 men and 162 women. The total area under cultivation in the *kebele* is 300 ha and 1 680 tonnes were produced during 2015/2016. The results of the household survey show that 0.2 ha is the average area of land allocated for maize production and the average amount of maize produced in 2015/2016 was 0.47 tonnes per household (Table 1.7). Tables 1.8 and 1.9 present information on (Intermediary) products and conversion factors as well as a detailed description of the FSC (Basics).

The key actors in the maize food supply chain (FSC) in Deder *Woreda* are farmers, cooperatives, transporters, traders, millers, warehouse managers of cooperatives, and daily labourers.

Based on the results of the evaluations under *Overview of the most important food supply chains in the maize sector* above, the selected supply chain comprises Harvesting → Stacking/Drying → Threshing (Shelling) → Storage →Rural Assemblers → Transport → *Woreda*/Zone Traders → Transport → Wholesalers → Transport → Retailers → Consumers (see Figure 2.1).

The FSC begins with maize grain being produced by smallholder farmers and ends with marketing of the grain to the consumers.

As seen in the flow diagram (Figure 1.1), the food supply chain is long. The longer the transaction of a given commodity the lower the efficiency of the supply chain, as the possibility of losses occurring at the different stages before the commodity reaches the consumer increases. Shortening the supply chain would increase its efficiency and contribute to the reduction of post-harvest losses.

Harvesting – Farmers harvest maize manually by cutting the stalks with sickles and detaching the ears later, while sometimes detaching the ears off the stalk standing in the field. Harvesting in the study area is in September (Table 1.9).

Stacking/Drying – Farmers further dry the maize by tying the maize stalks with the cobs into stacks in the field in an upright position and leave them to dry for some time.

TABLE 1.7
Description of the maize study site

Item	Average	SD
Total farm holding (ha)	0.3	0.1
Total cultivated area per household, ha	0.2	0.1
Total harvested crop per household, (tonne)	0.47	2.1
Major farming technology applied for maize (multiple responses)	(Percentage)	
Traditional	28	
Improved variety	88	

Source: Primary farmers survey data

TABLE 1.8
Products and conversion factors in the maize FSC – Intermediary

Activity in the process	Duration	Product out	Weight in tonnes from 100	Cumulative Error (± %)	Conversion factor
Harvesting	September	Maize ears	0.59		100
Shelling	October	Grain	0.47		87
Storage	Oct.-Feb.	Grain	0.47		100

Source: Farmers survey primary data, secondary data
Figures refer to an average household in the study area.

TABLE 1.9
Detailed description of the maize food supply chain – Basics

Stage in food supply chain	Geographical location	Months of the year		Main products	Quantity (tonne)	By-products	Quantity (tonne)	Services
		from	to					
Primary production		April	Aug.	Maize farm				
Harvest	Farmers' village	Sept.	Sept.	Maize ear (not dried)	3.76	Stalk	3.17	
Post-harvest handling	Farmers' village	Oct.	Oct.	Maize ear	0.59	Cob	0.12	Promotion of shellers by MoA and NGOs
Storage	Farm store	Oct.	Feb.	Maize grain	0.47			Promotion of PHLR technologies by MoA and NGOs
Transportation				Maize grain				
Market sales								

Source: Farmers survey primary data, secondary data
Figures refer to an average household in the study area.

Threshing/Shelling – Much of the maize shelling in the study area is with bare hands to strip the grain from the cob.

Transport from field to homestead – Farmers use sacks to transport maize from the threshing fields to the house using pack animals or human labour.

Storage – Farmers in the study area store their maize mostly by hanging the ears in a house using various structures. Shelled maize grain is kept in polypropylene sacks, though not for long periods.

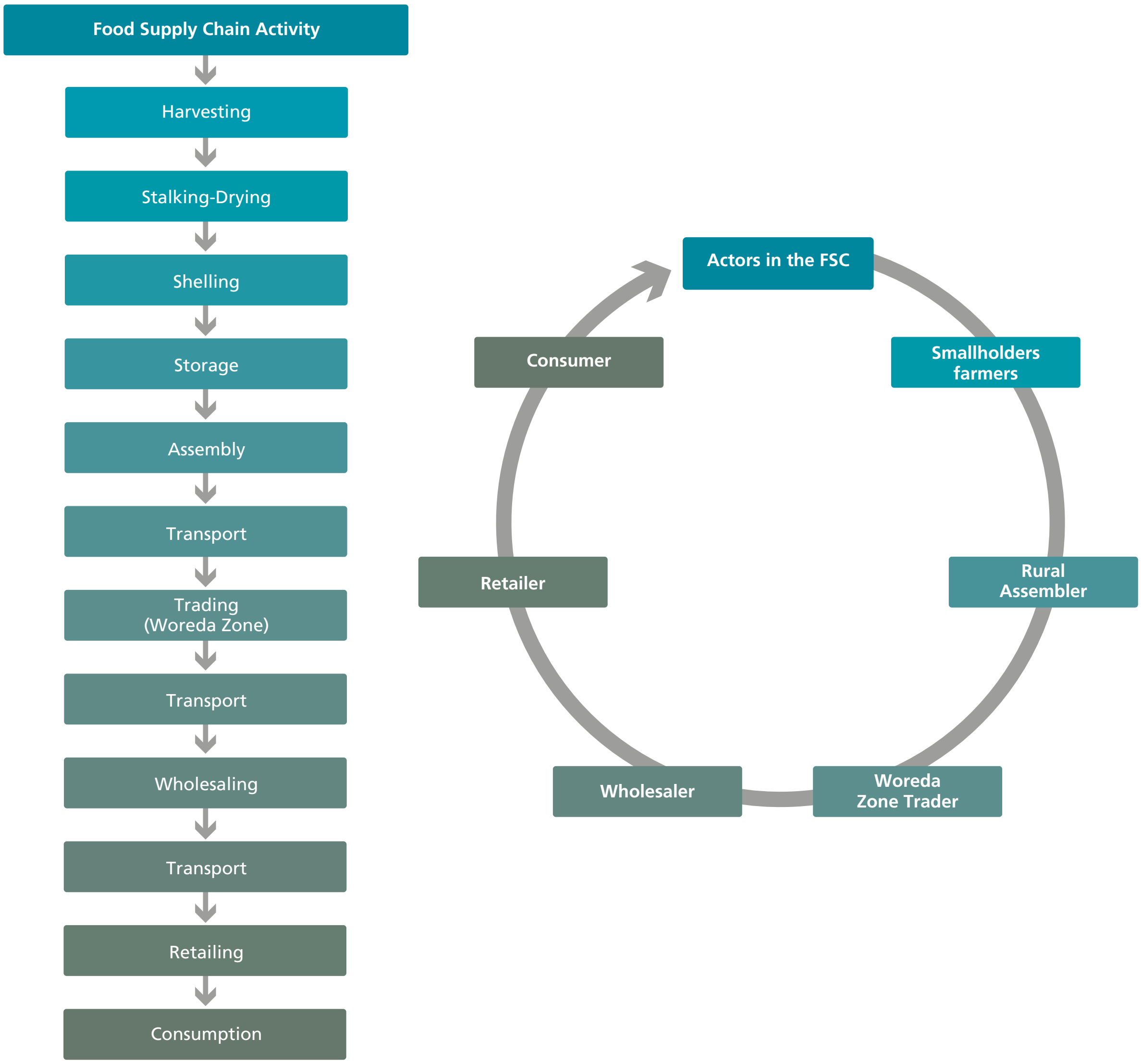
Assembly – Rural assemblers collect the maize surpluses from smallholder producers. Not much grain is assembled near farmers, however, because little surplus maize is produced in the study area.

Transport to the market – Farmers in the study area use polypropylene sacks to transport the maize grain to the market using pack animals or human labour.

Sales – Maize producers have different market outlets, the main being rural assembly (RATES, 2003). Rural assemblers collect the maize surpluses from smallholders in the farmers' areas. These assemblers are mostly independent operators in primary markets who assemble and transport the grain using pack animals and small trucks and sell to *woreda* or zone traders. These traders sell the grain to wholesalers in their area or urban centres. The wholesalers then sell to retailers. Finally, retailers solicit grain from the traders and sell to the users or consumers. Retailers play an important role in delivering the grain to the final consumer and handle about 38 percent of the total marketed volume of maize (RATES, 2003). Retail traders also collect maize directly from farmers.

There are no traders at the farmgate to collect or assemble the produce because little surplus maize produced in the study area. Those farmers producing maize in excess of their consumption sell their surplus either to retailers in the district (*woreda*) or directly to the rural or urban consum-

FIGURE 1.1
Flow diagram of the selected maize supply chain



Source: field data.

ers. Retailers in the study area source a minimum amount of maize grain from nearby farmers.

Milling – Millers are an important group of actors in the maize supply chain as they provide milling services to the community. An average miller in Deder town might handle as much as 240 tonnes of grain in a year, mostly maize, *teff* and sorghum .

THE MAIZE MARKETING SYSTEM

The staple food sector in Ethiopia has the weakest market institutions and infrastructure (Eleni, 2001). The marketed volume of maize passes through a number of channels before it reaches the final consumer, all performing various activities at different scales of operation, which is a model that can indicate inefficiencies in the value chain (IFPRI, 2010). Because of the involvement of a number of actors in the marketing system, the market is highly unreliable and the price differential between rural markets and the final terminal urban markets is enormous (ECX, 2009). Figure 2.1 shows the flow diagram for the selected maize supply chain.

As reported by FAO (2015), most traders have to sell the produce they buy as quickly as pos-

TABLE 1.10:
Views on the role of women in post-harvest handling of maize, Deder Woreda

Item	Frequency (N=25)	%
Do women participate in stacking/piling harvested grains? (Yes responses)	25	100
Who is responsible for managing traditional storage facilities?		
▪ Mostly women	5	20
▪ Men	1	0.4
▪ Both women and men	19	76
Who often finds out when grains are damaged by insects		
▪ Women	8	32
▪ Both women and men	17	68
Who is responsible for transporting grain to the market?		
▪ Mostly women	10	40
▪ Both men and women	15	60

Source: Farmers survey primary data

sible, rather than store it for sale later during the lean season, because of limited access to capital. The small volumes handled by traders, and the limited number of large-scale buyers, fragment the product or supply market. Large buyers also face the challenge of procuring a uniform and consistent supply of quality maize because there are no formal quality control institutions. Moreover, the market for maize does not provide price incentives for better quality and good handling practices. The domestic demand for maize is limited to urban areas where the purchasing power is relatively higher. Hence, as prices are often low with only about 20 percent of production destined for the market, maize is mainly for home consumption. Farmers in the study area sold their grain at the average price of USD 0.25 per kg.

Though retailers responded that they check grains upon buying, what they do if they receive lower quality is negotiate on the price, since the suppliers will have travelled long distances and they would not want to disappoint the farmers by rejecting the grain. Moreover, the prices are set through bargaining between buyers and sellers. Even though there are quality standards, none are used by traders and farmers.

SUPPLY CHAIN ACTORS' INVOLVEMENT, BENEFITS, JOB CREATION AND INCOME

Women play a key role in the production, harvesting, and post-harvest handling of maize, including storage, food preparation and consumption stages. Women should be more involved in efforts to reduce maize losses at all stages of the value chain, but specifically during storage and processing where they play a large role. Surveys in a wide-range of countries show that w*omen are responsible for 85 to 90 percent of the time spent on household food preparation* (WFP, 2013) and this illustrates that focusing food preparation training on women may reduce most food losses at the preparation stage.

Survey responses in Deder Woreda in Tables 1.10 and 1.11 indicate women's critical role in post-harvest activities. The results show that women farmers are active participants, either on their own or in collaboration with men, in many of the maize supply chain activities, in particular stacking and piling. This shows that targeting women in grain loss-reduction strategies is crucial to making a meaningful impact on efforts to reduce grain loss in all stages of the grain chain. As indicated in Table 1.11, women have an intermediate role in the primary production, harvest, sales and retail stages of the supply chain. However, their participation at the later stages of the supply chain in agroprocessing, storage, transportation and wholesale is low.

Traditional methods of primary production, harvesting and post-harvest handling (Tables 1.12 and 1.13), all contribute to losses that occur in the supply chain and negatively impact the environment. The traditional methods of primary production of maize result in low quality produce. Threshing by beating with sticks or trampling by animals causes mechanical damage of the grain. Moreover, storage of maize in traditional stores means the grain is vulnerable to storage pests and

TABLE 1.11
Detailed description of the maize food supply chain – Social structures

FSC STEPS	Involvement of women		Involvement of men		Who is mainly involved: women, men, children	Organization level of FSC actors	Gender / social patterns Observations and remarks that explain the chosen qualifiers and/or give additional information
	Girls	Adult women	Boys	Adult men			
	Qualifier*	Qualifier	Qualifier	Qualifier			
Primary production		2	3	4	Men	Individual level	Boys mostly help men do fieldwork
Harvest	1	2	1	4	Men	"	Boys and girls participate if there is a labour shortage
Post-harvest, handling		4	1	4	Women	"	Women are equally active in stacking and drying
Storage		4		3	Women	"	Women are more active in storage management
Transportation		3		4	Men	"	Men are more active in transportation to market while women are more active in transportation for milling
Market sales		2		4	Men	"	Sales dominated by men
Agroprocessing		1		3	Men	"	
Storage		1		4	Men	"	
Transportation		1		4		"	
Wholesale		1		4		"	
Retail		2		4	Men	"	

* Qualify the gender participation level, 4: high, 3: good, 2: moderately good, 1: low.
Source: Farmers survey primary data and secondary data

TABLE 1.12
Detailed description of the maize food supply chain – Environment

Production		**Quantity***	**Unit**
Tools, Equipment, Facilities	Ox-drawn plough set	1	Set
	Hoes, knapsack sprayers, sickles	1 each	Piece
Materials, Chemicals	Fertilizers	40	kg
	Herbicides	0.2	litres
Energy	Oxen power	1	Pair
Land		0.2	ha
Storage		**Quantity**	**Unit**
Tools, Equipment, Facilities	Traditional storage structures	1	
Materials, Chemicals	Polypropylene bags	5	Piece
Transportation		**Quantity**	**Unit**
Tools, Equipment, Facilities	Polypropylene bags	5	Piece
Energy	Pack animal (Donkey)	1	Individual

* Quantities refer to an average household in the study area.
Source: Farmers survey primary data and secondary data

TABLE 1.13
Factors for the environmental assessment

Factors	Description	Details
Type of production system	Traditional	Ox-drawn plough, manual hoeing, manual harvesting, shelling...
Land preparation practices	Ox-drawn plough	
Soil quality and land degradation	Low land and water conservation	Mono cropping of maize less soil conservation practice causes soil degradation
Sources of GHG emissions	Low	Losses and by-products are used
Utilisation of residues in the supply chain	Maize stalk is used as feed, for construction and firewood and cobs used as firewood	
Re-use of food losses	Used as animal feed	

Source: Farmers survey primary data and secondary data

rodents, thus potentially resulting in significant losses. Even though the use of losses and by-products for different purposes minimize their direct effect on the environment (e.g. GHG emissions), indirect effects such as deforestation may be caused by farmers' lack of a safe power source.

Chapter 3
Food losses – study findings and results

DESCRIPTION OF THE MAIZE FOOD SUPPLY CHAIN – RISK FACTORS

In Deder *woreda*, maize production faces a number of risks. These include climatic variability such as shortage of rain (where irrigation is very limited), pest infestation during growing and maturity and attacks by domestic and wild animals. Harvesting, stacking, threshing, transportation and storage activities pose the risk of quantitative and qualitative losses. For example, farmers are likely to lose their production if they harvest maize late. Maize losses may also occur during harvesting because the cobs may be lost at the stalking and drying stages.

Maize is also likely to be lost during transportation if farmers do not use good quality bags. Loading and unloading has its own risks, since bags may be punctured because of rough handling. According to a retailer from Deder town, the average loss of grain per loaded truck, with a carrying capacity of 4.5 tonnes, is 20 kg. Another retailer estimated that the activities of loading, transporting and unloading may contribute to 5 percent of the total grain loss. Union warehouse managers indicated they provide orientation for labourers working in warehouses to ensure proper handling of maize loads during unloading and loading to reduce maize loss in the event bags are torn. One union official estimated that 5 to 8 percent of grain loss occurs during handling in warehouses. A respondent engaged in buying maize from farmers stated that local traders in Deder town encourage farmers to use new bags to store their maize, but farmers resist because of the additional cost involved.

Local traders argue that the quality and quantity of maize decreases with aging, as maize stores are vulnerable to pest and insect infestations. Maize damaged by insects becomes cattle feed sold at much lower prices. However, local traders sometimes use poor maize quality as a pretext for lowering the price of maize bought from farmers. In this regard, cooperatives offer alternative market channels for maize farmers.

Table 1.14 indicates estimates of the relation between some risk factors and food loss. Here, the purpose is to have an idea of the most important factors influencing food loss, though it is difficult to quantify properly using statistical methods for one season and one FSC. Accordingly, pest resistance, training, knowledge and awareness of farmers, rainfall amount, good farming practices, such as the right time to plant and harvest and

TABLE 1.14
Food loss risk factors

Variable	Unit	Expected Status	Reducing Loss – Estimated percentage value contribution (observed in the case study)
Crop variety	Type	Pest resistant variety	10
Good Agricultural Practices (GAP)	Y/N	Yes	20
Rainfall during production	mm	Optimum range	15
Training and knowledge about the causes of losses	Y/N	Yes	20
Others, such as the use of pesticides, botanicals and mixing with ash for storage pest control			35

Source: Farmers survey primary data and secondary data

TABLE 1.15
Summary result matrix of maize food losses

FSC Stage/Process		Percent-age quantity lost in the activity/ step*	Cause of loss/Reason for low loss	Economic loss (ETB/100 kg of grain)	CLP /LLP	Impact/ stakeholders affected (men / women)	Perception of stakeholders (men / women)	Suggested solutions
Production	Harvesting	1.0	Ear detachment	5.5		Farmers		
	Stacking	2.1	Damage by rats and domestic animals	11.0		Farmers		
	Threshing/ Shelling/	0.5	▪ Spillage from threshing floor ▪ Impurity and broken grains when shelled by beating with stick	2.4	Low loss because most shelling is done by hand	Farmers	Hand shelling is more efficient but is time consuming, much impurity and broken grains when shelled by beating with stick	- Use shellers - Clean grain after shelling
Farmers' transportation		0.4	Spillage	2.1		Farmers	Use of old bags result in spillage loss	Use new (undamaged) bags
Farm storage		6.9	▪ Insect pests and discoloration	36.6		Farmers	Poor storage in used Bags, Poor sanitation of stores	Use hermetic storage such as metal silo or triple bags
Wholesale		1.75	▪ Weight loss results from further drying ▪ Spillage because of old bags and labour-ers' negligence ▪ Insect infestation ▪ Impurity	9.3				
Retail		4	▪ Impurity related to poor threshing floor ▪ Broken grains when shelled by hitting with a stick ▪ Improper drying resulting in grain discoloration, insect damage	21.2		Traders	Impurity and broken grains when shelled on poor threshing floor or shelled by hitting with stick, mixture of immature grains, Improper drying	

* Loss figures are estimates from the actors of the FSC.
USD 1 = ETB 21; Price of 1 kg *maize* grain = USD 0.2524
Source: Primary farmers survey data

storage practices, are important in reducing the risk factors related to food loss.

CRITICAL LOSS POINTS IN THE MAIZE SUPPLY CHAIN

Generally, at the smallholder farmer level, maize post-harvest losses are at harvesting, stacking/drying, shelling and storage. Quantitative loss estimated at each respective step in the food supply chain and the related reductions in market value and the causes of losses are shown in Table 1.15.

Harvesting – Farmers in the study area estimated a loss of 1 percent of their maize at harvesting.

Stacking – Farmers estimated 2.1 percent loss during stacking of harvested ears on the stalks.

Shelling – According to the farmers in the study area quantitative loss at the shelling stage is 0.5 percent.

Transport – Respondent farmers estimated 0.4 percent loss from spillage of grain from damaged bags while transporting from the threshing floor to home/store or to the market.

Storage – The greatest loss farmers reported is 6.9 percent because of insect damage and discolouration because damaged bags are used and poor hygiene. The load tracking assessment showed 33 percent quantitative loss because of reduced quality.

Retailing – Respondent retailers in Deder town reported an average loss of 4 percent.

Wholesaling – There were no wholesalers in the study area. However, those interviewed were from the study area's zone town (Harar), three from East Shewa Zone (Adama Town) and two from the capital Addis Ababa. The wholesalers obtain maize from West/East Wellega, Shashemene, Bir Sheleko farm and Wolayita. Traders from these areas bring grain that has been ordered to their stores after prior contact with the retailers. Wholesalers estimated quantitative losses of 1.75 percent. The causes of these losses include:

- weight loss resulting from further drying of grain supplied to them;
- spillage because old bags are used and negligence of the labourers; and
- insect infestation and presence of impurities.

LOAD TRACKING AND SAMPLING METHODS

Storage at the farmer level is a critical loss point. The largest portion of stored grain at the farmer level was of poor quality and sold at a low price. The researchers determined loss of quality and quantity in storage from results obtained on maize samples collected from a selection of nine farmers in Burka Golu *Kebele*, before and after storage. The researchers used 1 kg samples collected from farmers' stores to estimate losses based on parameters for maize given in Table 1.16. Detailed results are shown in Table 1.17.

QUALITY ANALYSIS

The quality analysis data showed that a significant proportion of the maize grain (67 percent) was categorized as unfit (score 0) before entering storage (Table 1.18). Highly and moderately damaged and broken kernels and diseased and immature

TABLE 1.16
Quality scoring of maize grain

Product	**Maize grain**	
Quality score	***Description of the quality***	***Percentage reduction of market value***
0	Greater than 10 percent damaged, shrunken, weevil kernels and broken grain. Overall impurity greater than 15 percent. Beside (despite) the impurity, existence of live insects	Loss of 17 percent market value
1	Free from live insects with tolerance up to 10 percent of damaged, shrunken, weevil kernels and broken grain and overall impurity between 8 and 15 percent	10 percent loss of the market value
2	Free from live insects with 5.5 percent damaged, shrunken, weevil kernels and broken grain and overall impurity not exceeding 8 percent	Market offers ETB 530 per quintal (100 kg) for better quality grain (the price referred is a local market price)

Source: Load tracking and sampling data

TABLE 1.17
Quality analysis of maize in sampled units

Unit Evaluated	Overall Quality Score	Type of damage (deterioration) if any	Potential cause and symptoms
1	0	Physiological, pathological non-compliance with standards	Symptoms: highly damaged, broken kernels, diseased grain, immature grain and presence of live insects Cause: poor farm and store management
2	0	Physiological, pathological non-compliance with standards	Symptoms: highly damaged, broken kernels, diseased grain, immature grain and presence of live insects Cause: poor farm and store management
3	0	Pathological non-compliance with standards	Symptoms: moderately damaged, broken kernels, diseased grain, immature grain and presence of live insects Cause: poor farm management and storage
4	0	Pathological non-compliance with standards	Symptoms: moderately damaged, broken kernels, diseased grain, immature grain and presence of live insects Cause: poor storage management
5	0	Pathological non-compliance with standards	Symptoms: moderately damaged, broken kernels, diseased grain, immature grain and presence of live insects Cause: poor farm and store management
6	0	Physiological, pathological non-compliance with standards	Symptoms: highly damaged, broken kernels, diseased grain, immature grain and presence of live insects Cause: poor farm and store management
7	0	Physiological, pathological non-compliance with standards	Symptoms: highly damaged, broken kernels, diseased grain, immature grain and presence of live insects Cause: poor farm and store management
8	0	Physiological, pathological non-compliance with standards	Symptoms: highly damaged, broken kernels, diseased grain, immature grain and presence of live insects Cause: poor farm and store management
9	0	Pathological non-compliance with standards	Symptoms: moderately damaged, broken kernels, diseased grain, immature grain and presence of live insects Cause: poor farm management and storage

Source: Load tracking and sampling data

grain are the major symptoms, which are caused by poor field management and post-harvest handling. After storing the grains for five weeks, 100 percent of the sample was categorized as unfit (score 0). The main symptoms are the presence of live insects and an overall impurity ranging from 3 to 33 percent The main cause is the use of inadequate storage structures, which are not insect-proof, and poor management.

Traditional storage structures and poor storage conditions expose the grain to insect attack and provide favourable conditions for the proliferation of insects, micro-organisms and rodents. The situation is aggravated by poor farm management practices.

Table 1.18 also shows that before storage, 22 percent of sampled grain was of low quality. The quality of these grains after storage deteriorated to the unfit category because of continued insect damage. Therefore, there was a 22 percent reduction in quality and the percentage lost (quantitative loss) as a result of reduced quality was 33 percent. This result is much higher than the level of loss reported by farmers of 6.9 percent. In this study, the value of 6.9 percent is the basis on which proposals have been developed to reduce losses.

Causes of the losses at each step of the FSC are described in the following section:

CAUSES OF MAIZE LOSSES AND IDENTIFIED LOSS REDUCTION MEASURES

The study discusses the causes of post-harvest losses at the different stages of the selected FSC following.

Harvesting – The causes of losses at harvesting are:

TABLE 1.18
Presentation of load tracking and sampling results

A	Product	Maize			
B	Event	Storage			
C	Duration of the event	5 weeks			
D	Location	*Kebele*/Village			
	Before the event	**Experimental Unit**	**Weight of Unit in kg**	**No. of unit**	**Total weight**
E	Load	Farmer (traditional store)	416	27	11 232
F	First stage sample	Farmers 'stored grain	416	9	3 744
G	Second stage sample	Grain sample/scoop	1	9	9
		Value (score/percentage)	Causes		
H	Sample size second stage	9 kg			
I	Average quality score (0-2)	0.4	Poor harvest and post-harvest handling resulted in grains that are immature, broken and discoloured and the presence live insects		
J	Percentage unfit (0)	67	Poor harvest and post-harvest handling resulted in grains that are immature, broken and discoloured and the presence live insects		
K	Percentage low quality (1)	22	Poor harvest and post-harvest handling resulted in grains that are immature, broken and discoloured		
	After the event	**Experimental Unit**	**Weight of Unit in kg**	**# of unit**	**Total Weight**
L	Load	Group of Farmer (traditional store)	416	27	11 232
M	First stage sample	Farmers' stored grain	416	9	3 744
N	Second stage sample	Grain sample/scoop	1	9	9
		Value (score/percentage)	Causes		
O	Sample size second stage	9 kg			
P	Average quality score (0-2)	0			
Q	Percentage unfit (0)	100	The main factor for quality deterioration is poor storage management that resulted in presences of live insects in almost all samples.		
R	Percentage low quality (1)	0			
	Quantity loss	**Value (Percentage)**	**Causes/Observation**		
S	Percentage lost (E-L)/E)	0	Here it is hard to see the change in quantity as all the maize was not threshed yet		
	Quality loss	Value (Percentage)	Causes/Observation		
T	Percentage lost (Q-J)	33	The traditional storage techniques and limited treatment at farmer level seem to create a conducive environment for the development of insect pest infestation		
U	Percentage quality reduction (R-K)	-22			

Source: Load tracking and sampling data

- The detachment of some cobs off the stalks while cutting. When farmers concentrate on cutting the stalks and carrying them to stacking corners, detached cobs accidentally fall onto the weedy ground and are lost; or
- The loss of harvested cobs during collection and transportation to the drying area. When farmers harvest by detaching the cobs from the stalks, they put batches of cobs on the ground and continue harvesting. Farmers inadvertently miss some batches during collection for drying. Moreover, it may rain when the maize field is ready for harvest, causing grain spoilage.

Stacking – Rats and domestic animals damage maize in stacks. Farmers usually fence stacked maize to keep animals out and put rodenticide down to control rodents.

Shelling – Losses during maize shelling occur because of the breakage of kernels and spillage of grain from the threshing floor during shelling. In the study area, however, the loss at this stage is low because shelling is by hand, which is tiresome and time consuming.

The use of shelling machines could help reduce losses at this stage in major production areas.

Transport from field to homestead – Losses during transportation are minimal and not worth considering. The small losses can be avoided by using sound bags.

On-farm storage – There are many reasons as to why a significant portion of sampled maize is unfit after storage at the farmer level. Traditional storage structures expose the grain to infestation by insect pests, micro-organisms and rodents. Losses during storage are because of insect infestation as a result of poor storage management and poor sanitation. Also if wet grain is stored and not dried properly the grain will spoil. Farmers reported that this problem occurs when it rains during harvesting, coupled with lack of sunshine to dry the grain.

Retailing – in Deder town it was reported that losses are because of impurities, broken and discoloured grains, immature grains and insect damage. The impurities are because farmers shell on unprotected ground. It was also reported that shelling by beating with sticks causes grains to break, while grain becomes discoloured when it is not dried properly. Retailers also believe that discoloration occurs when there are immature grains because of early harvesting before maturity. The presence of storage insects might be because of negligent pesticide applications or mixing the previous seasons' production with the new crop.

Wholesaling – losses were attributed to weight reduction as a result of further drying because the grains they buy are not well dried. Causes considered included losses from spilled grain during unloading, as old bags may be used by the supplier, labourer's negligence, insect infestation and impurities.

As a good practice in post-harvest loss reduction, the wholesalers inspect the grain they buy for signs of pest infestation, moisture content, grain colour and level of impurities. Whenever grains show symptoms of insect infestation, the bags are separated and immediately fumigated.

THE MAIN ACTORS AND THEIR ROLES IN MAIZE FSCS AND FOOD LOSSES

Farmers face grain losses during harvesting, stacking, shelling, transportation and storage activities because of the traditional methods of grain handling (Table 1.19).

Maize losses occur from spoilage because of excessive moisture, as identified by farmers who responded to the survey. Maize losses also occur because farmers harvest before maize adequately matures, according to a cooperative official in Deder *woreda*. Farmers estimated that on average 1 percent of maize is lost during harvesting.

Broken maize seed is also common because of improper shelling practices, when maize is stored for too long it is exposed to pest infestation, a major cause of poor quality maize.

Cooperatives, as post-harvest food handlers, play a role in the occurrence of losses. Maize loss occurs during storage when maize is stored for too long, because it has not been treated with pesticide, poor quality bags are used and storage quality is low, as they store is made of mud-plastered walls and bare ground floors, which leaves the grain exposed to excessive moisture and pest infestation. Losses also occur during loading and unloading as a result of spillage from punctured bags.

Loss of maize during handling by maize traders occurs during the collection of maize in small quantities. In particular, retail traders experience maize losses during weighing, packing, loading and unloading. Labourers who might not have experience in handling bags with care are mostly engaged in these activities. Interviewed retail traders estimated an average loss of 4 percent. Grain loss occurs at the point of milling when the grain is weighed and poured into the funnel of the milling machine. Grain loss also occurs when customers put the grain in old bags, and when grain handlers do not carry the bags properly.

Millers indicated that the losses are often borne by customers who bring their grain to the millers. Estimates are that customers lose 4 kg per quintal (100 kg) during milling.

Interactions among the different actors have an impact on the maize FSC. For example, if cooperatives train their members in maize stor-

TABLE 1.19
Description of key actors in the maize supply chain and their roles, Deder *woreda*

Actors	Role	Impacts on maize loss
Farmers	Produce, harvest, pile, thresh and transport maize from cropping fields to house	Maize loss can occur during harvesting, stacking, threshing, transporting and storing as traditional methods are employed
Cooperatives	Supply farm inputs for farmers, market consumable items (e.g. sugar) to members, buy maize from farmers, sell maize to farmers in times of food shortages	Maize loss can occur during transportation, handling and storing as a result of poor quality packing material or poor handling
Traders	Act as intermediaries between farmers and consumers	Loading and unloading grains expose grains to loss resulting from punctured bags, spillage, etc. Poorly managed stores by traders also cause maize loss
Transporters	Provide transport services for local traders	Maize may be lost if it is not properly packed in sacks
Warehouse managers	Manage grain storages	Stores characterized by excessive moisture, lack of ventilation and irregularly cleaned maize expose the grains to pests, insects and moisture
Millers	Grind maize for consumers, sell maize to local consumers	Care should be taken when transferring maize from bags into the tunnel-like-grinding machine

Source: Farmers survey primary data

age, maize farmers can reduce the amount of food losses resulting from poor storage. In this regard, however, not a single survey respondent had received training in grain handling in the last three years.

Farmers also store their maize in small bags (50 kg) and the use of good quality bags would contribute to a significant reduction in maize losses. Cooperatives can play an important role in ensuring bags are made available to farmers at affordable prices.

LOW LOSS POINTS

The study identified low loss points as shelling and transportation, with only 0.4 percent losses recorded at both stages of the supply chain. Low losses at shelling are largely explained by the fact that shelling is done by hand in the study area. However, shelling by hand is not recommended, as it is labour and time intensive and tiresome. Losses are low during transportation because farmers use sound bags which reduce spillage.

Chapter 4
Food loss reduction strategy for maize – conclusions and recommendations

IMPACT OF FOOD LOSSES IN THE SELECTED MAIZE FOOD SUPPLY CHAIN

Farmers expect to lose over 10 percent of their maize during post-harvest activities, an amount that considerably impacts household food security and income. On the other hand, load tracking sample analysis at the point of storage showed that 33 percent of the stored grain is lost after five weeks of storage.

Farmers are the main victims of maize losses because of bad handling of the crop during harvesting, threshing, transportation and storage. In surplus maize-production areas, significant losses occur at shelling. For smallholder farmers, the critical loss, in terms of quantity and quality, occurs during storage where the use of traditional storage facilities exposes the maize crop to wastage resulting from pest infestation.

Food loss reduces food availability at the household level and increases smallholder farmers' vulnerability to climate change as reflected by frequent droughts. The production of unusable food also wastes farm household labour. Deder farmers allocate up to a quarter of a hectare of land for the production of maize, a portion of which would be lost at various stages of the maize FSC. Farmers also invest their limited financial resources to buy chemical fertilizers, improved seed, to increase maize production but some would be lost without reaching the producers' storage. Overall, grain loss leaves smallholder farmers at risk of food insecurity because the losses negatively impact the amount of food available for the household.

The impact of post-harvest maize grain loss on retailers is considerable. They estimated a loss of 4 percent because of impurities and broken kernels in the grain they buy, improper drying, grain discolouration and damage by storage insect pests. These losses pose economic impact worth USD 360 per retailer per year.

ENVIRONMENTAL IMPACT

The literature is relatively new on the impact of food loss on the environment in terms of depletion of land and water resources and increased GHG emissions. To compensate, production shortfalls resulting in part to grain loss during production, harvesting and storage, farmers are compelled to use more land, water and chemical fertilizers, all of which impact the environment as their use leads to the depletion of the natural resource base for food and agriculture. This would also have a negative impact on climate change and smallholder farmers' capacity to adapt to the climate and would affect their resilience.

However, maize producers in Deder do not seem to be concerned about the environmental impact of grain loss (Table 1.20). Most agreed that food loss has no negative impact on the environment. Although farmers are aware of the variability of the weather and the changing climate, they generally do not claim that their farming practices cause or aggravate these changes. Farmers cope with a lack of rainfall and variable climate by growing short maturing varieties, engaging in non-farm activities and changing the crops they grow and animals they keep. For example, a cattle-herder may switch to raising goats after selling cattle.

The fact that farmers pay little attention to the impact of food loss arises from their failure to appreciate the magnitude of grain loss during production, harvesting, shelling and storage. This view is consistent with the results of interviews with the main respondents. The direct environmental impact of food loss was not perceived, especially in terms of causing environmental pollution from accumulation of unused, leftover and wasted food. There is a need for education at all levels to raise awareness of the extent of grain loss and its impact on the environment, climate change and rural household food security.

TABLE 1.20

Views regarding environmental impacts of maize grain loss

Item	Maize	
Do you think food loss impacts the environment negatively?	Yes (Percentage)	No (Percentage)
	4	96
Do you think food loss aggravates depletion of the natural resource base (e.g. land, water, etc.)	Yes (Percentage)	No (Percentage)
	4	96
What kind of impact has agriculture on environment in general:		
▪ Positive	72	
▪ Negative	24	
▪ Neutral	0	
▪ Not sure	4	
Do you think the application of chemical fertilizers in the production of grains impacts the environment negatively?	Yes (Percentage)	No (Percentage)
	52	48

Source: Farmers survey primary data

COST-BENEFIT ANALYSIS OF THE FOOD LOSS REDUCTION MEASURES IDENTIFIED

Harvesting and post-harvest handling

Losses during maize shelling in the study area were very low because shelling is by hand. However, based on the information obtained from the main respondent experts and the authors' experiences, shelling is the first step that is presumed to be a critical loss point in the selected maize supply chain, with respect to both quantitative and qualitative losses.

Various organizations are currently demonstrating and popularizing *diesel powered maize shellers* that are locally available. Observations showed that farmers liked the technology, though its affordability is questionable as it costs between ETB 50 000 and 60 000. A few farmers who managed to buy the shellers are benefitting from the shelling services they provide to other farmers on a rental basis. Therefore, efforts should be made to encourage farmers in surplus maize production regions to buy shellers (at least in groups), through the facilitation of financial support that allows for credit.

The development strategy of the Agricultural Transformation Agency, working document 2013–2017 (ATA, Undated) stresses the unavailability of shelling and cleaning equipment and the need to promote appropriate technology. Machine calibration and maintenance centres that are accessible to farmers are also necessary. In the case of the study area, where maize production is limited, *hand operated maize shellers* could be introduced to replace farmers' practice of shelling by hand and serve a group of farmers.

Storage

Farmers should store fully dried grain and keep storage areas clean. Farmers need training in determining grain moisture content using salt and a glass bottle. Storing the crop in hermetic storage, such as metal silos and triple bags, protects stored grain from storage losses resulting from insect pests. Such storage structures can provide effective protection of the grain so long as they are air tight without the use of pesticides. Metal silos also safeguard grain from rodents.

Metal silos of different storage capacities are made by local artisans and available at USD 140, 165 and 190 for capacities of 300 kg, 500 and 1 000 respectively. If properly handled, metal silos can serve up to 15 years or more. This would address losses from individual farmers resulting from poor storage conditions that cause spoilage, spillage and insect pest and rodent damage.

Table 1.21 shows that the solution is not profitable, if applied to one farm household, despite the savings realized from reduced losses. The cost of buying and operating a 500 kg silo is too high for a farm household. It is therefore advisable that unions and private suppliers provide these storage services to farmers or groups of farmers on a rental basis.

Government and NGOs should promote the use of silos through the dissemination of knowl-

TABLE 1.21
Budget calculation for food loss reduction (Metal silo for grain storage of maize of 500 kg capacity)

	Item: metal silo for grain storage (500 kg capacity)	Value	Unit
a	Product quantity	0.47	tonne/year
b	Product value	252.4	USD/tonne
c	Loss rate	6.9	%
d	Anticipated loss reduction	75	%
e	Cost of intervention	165	USD
f	Depreciation	10	years
g	Yearly costs of investment	16.5	USD/year
h	Yearly costs of operation	Negligible	USD/year
i	Total yearly costs of solution	16.5	USD/year
j	Client costs per tonne product	35	USD/tonne
k	Food loss	0.0324	tonne/year
l	Economic loss	8.2	USD/year
m	Loss reduction	0.0243	tonne/year
n	Loss reduction savings	6.15	USD/year
o	Total client costs	16.5	USD/year
p	Profitability of solution	-10.4	USD/year

Source: Farmers survey primary data and the load tracking data

edge and improving access to financial services for farmers and small enterprises. As some farmers may fail to afford buying or renting metal silos, facilitation of credit services would enhance their dissemination and use.

Triple bags such as PICS bags are effective in protecting grain from damage by storage insect pests, as they create hermetic conditions that curtail insect infestation. These bags are locally available at affordable prices of USD 1.6 at factory gate, USD 1.8 at distribution centres and USD 2.1 at farmgate. Farmers can reuse PICS for 2 to 3 seasons, if properly managed. Hence, a PICS bag bought for about USD 2.1 at the farmgate and serving for 3 years is profitable and worth promoting. Tables 1.21 to 1.23 depict a cost benefit analysis of the metal silo and PICS bag technologies and related implications.

FOOD LOSS REDUCTION STRATEGY, PLAN AND INVESTMENT REQUIREMENTS FOR MAIZE

Awareness creation

Asked to indicate the main problems that constrain their use of modern post-harvest reduction technologies, farmers responded they either receive inadequate advice from the institutions concerned (68 percent) or lack the knowledge (80 percent) of the technologies. Therefore, the first and foremost intervention should be to build the capacity of maize farmers, and other supply chain actors including policy-makers, on the importance of post-harvest losses, the effect on food security and climate resilience and economy thereby acquainting them with the various measures required to reduce losses. This would be accomplished by training workshops and media broadcasting.

Given that many smallholder farmers in developing countries live on the margins of food insecurity, a reduction in food losses could have an immediate and significant impact on their livelihoods (FAO, 2011). Reducing post-harvest losses indirectly translates to reduced use of production

TABLE 1.22
Budget calculation for food loss reduction – Triple bag for maize grain storage

	Item: triple bags for grain storage	Value	Unit
A	Product quantity	0.47	tonne/year
B	Product value	252.4	USD/tonne
C	Loss rate	6.9	%
D	Anticipated loss reduction	75	%
E	Cost of intervention	10.5	USD
F	Depreciation	3	years
G	Yearly costs of investment	3.5	USD/year
H	Yearly costs of operation	Negligible	USD/year
I	Total yearly costs of solution	3.5	USD/year
J	Client costs per tonne product	7.4	USD/tonne
K	Food loss	0.0324	tonne/year
L	Economic loss	8.2	USD/year
M	Loss reduction	0.0243	tonne/year
N	Loss reduction savings	6.15	USD/year
O	Total client costs	3.5	USD/year
P	Profitability of solution	2.65	USD/year

Source: Farmers survey primary data and the load tracking data

resources (land and water) and inputs that directly impact the environment. Raising awareness would therefore reduce the negative impact of post-harvest losses on the environment.

Popularization and scaling up of available post-harvest loss reduction technologies

Technologies proven to reduce PHL, such as maize shellers, metal silos and triple-bags, should be persuasively and systematically promoted to the smallholder farmers. This should commence with practical demonstration of the technologies for model farmers, accompanied by field day visits by as large a number of farmers as possible and other actors to show the effect of these technologies on PHL reduction.

Stakeholders' Synergetic Action

Various stakeholders are working to reduce post-harvest losses. However, it has not been possible to achieve the required goal of reducing losses. Combining efforts and acting in synergy would help optimize resources and maximize efficiency of actions. It is therefore important to bring stakeholders from the production stage all the way up to the consumption point into a common innovation platform where they identify problems, seek solutions, share responsibilities and act accordingly with the utmost collaboration.

Strengthen institutional support

Respondent farmers also reported that the high costs of post-harvest loss reduction technologies hampered their uptake. Institutional support such as facilitating credit to buy technologies and linking actors to markets that pay premium prices for quality would hasten the uptake of available technologies and enhance PHL reduction efforts.

Strengthen post-harvest research

Actors are so far doing little to reduce food losses, research the status of PHL of food grains and generate appropriate technologies. Recently, PHL received special attention as the Ethiopian Institute of Agricultural Research developed a policy to implement a 15-year strategic plan for post-harvest research. The National Agricultural Research System should be strengthened to enable the generation of timely solutions to prevent post-harvest bottlenecks.

TABLE 1.23
Summary of maize food losses, causes and solutions

Critical Loss Point	Magnitude of losses in the FSC			Cause of loss	Intervention to reduce losses	Loss reduction		Cost of intervention (USD/yr	Economic implications	Social implications	Food security implications	Environmental and climate change implications	Policy implications
	Percent-age	Weight tonne/ year	USD/yr			Percent-age	Savings USD						
Storage in metal silo	6.9* (Qn)	0.0324	8.2	Damage by insects and rodents	Metal silo	75	6.15	16.5	- Increased income, - Fetch better price/market	Improved livelihood (better education and health), employment opportunity	Contributes to food security - availability - safety - nutrition	Free from chemicals, wasted minimized	Ensured food security, better society for better development, better source for agro-industry
Storage in triple bag	6.9* (Qn)	0.0324	8.2	Insect damage	PICS bag	75	6.15	3.5					
Storage	22* (Ql)		11.9										

Source: Farmers survey primary data and the load tracking data
* Result of the survey assessment
NB: Qn = quantitative and Ql =qualitative
The qualitative losses after 5 weeks of storage are estimated at 22 percent (results of the analyses on samples). The product loses 10 percent of its market value.

Encourage private sector involvement

The private sector should contribute much to the reduction of post-harvest losses particularly through participating in the production and distribution of improved harvesting, transportation, shelling, cleaning, storage and preservation technologies (e.g. Shayashone Agribusiness Consultant Manufacturing PICS bags). The private sector can also supply the necessary consumable inputs to the post-harvest value chains.

FOLLOW-UP ACTION PLAN – CONCEPT NOTE

According to the respondent farmers, a loss of 1 percent occurs during harvesting because of breaking of maize cobs when they are cut from the stalks. About 2.1 percent loss occurs during stacking. It was also estimated that farmers lose 0.5 percent because of grain spillage during shelling and 0.4 percent during transportation. Hence, the above-mentioned steps are *low loss points* in the study area, although they add up to 4 percent of losses of the harvestable grain before reaching the farmers' store. The presence of impurities and broken kernels in the produce as shelling is carried out by beating with sticks on unprotected threshing floors, may reduce the selling price and impact farmers' income.

The highest loss farmers suffer (6.9 percent) is during storage, mainly because of insect damage. These losses are because of poor storage structures and post-harvest handling that attract insect infestation. This stage of the selected food supply chain is the *critical loss point*. Intervention at this stage would make a significant difference.

As indicated above, wholesalers in the study area believe they lose 1.75 percent of the maize grain they transact because of loss of weight (the grain they purchase is improperly dried), spillage (their suppliers use old bags), insect infestation and the presence of impurities in the grains. Traders suffer relatively low losses because they do not store for long and use comparably better storage. However, the estimated losses from traders' annual transactions pose a considerable economic impact of USD 1 637.8 per trader.

Maize shellers

In the study area, where maize production is limited, it could be worth introducing *hand operated maize shellers* to replace farmers' manual shelling practices. Manual shelling is mostly done by women. Hand operated shellers can serve a group of farmers and relieve women of the tiresome and time-consuming process of shelling with their hands.

The authors of the case study recommend the use of motor-operated maize-shelling machinery in major or surplus maize-production areas, to avoid the laborious shelling activity that results in considerable losses. Governmental and non-governmental organizations have demonstrated this machinery. Observations showed that farmers liked the technology, though whether farmers could afford the technology is questionable. On the other hand, the few farmers who managed to buy a sheller are benefiting from the provision of shelling services to other farmers on a rental basis.

Therefore, farmers in major, surplus maize production regions could buy shellers in groups or through cooperatives. Facilitation of financial support on a credit basis, where needed, is worth considering. Youth might join the maize-shelling service business after technical training and financial support as a long-term loan, coupled with arrangements for machine calibration and maintenance centres that would be accessible to the farmers.

Metal silos for grain storage

Metal silos of different capacities (300, 500 and 1 000 kg) are made by trained artisans and can easily be made available. Farmers need to be encouraged to use this technology to protect their produce. It is advisable that unions and private suppliers provide these services to farmers or groups of farmers on a rental basis. To promote the use of silos, knowledge-dissemination and improved access to financial services for farmers and small enterprises should be employed. As some farmers may fail to afford to buy or rent metal silos, facilitation of credit would enhance the dissemination of the silos and their use.

On the other hand, the capacity of the artisans' production is not sufficient to satisfy large-scale promotion of the technology. It is therefore necessary to encourage more artisans near the farmers to fabricate metal silos after training and other types of support.

Triple bags for grain storage

Triple bags such as PICS bags are effective in protecting grain from damage by insect pests, as they create hermetic conditions that kill insect infestation. Farmers can reuse PICS bags for 2 to 3 seasons, if properly managed. Hence a PICS bag that is bought for about USD 2.1 and serving for an average of 3 years is profitable and worth promoting.

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