Postharvest loss assessment of maize, wheat, sorghum and haricot bean

A study conducted in fourteen selected woredas of Ethiopia under the project -GCP/ETH/084/SWI

FOOD AND AGRCICULTURAL ORGANIZATION OF THE UNITED NATIONS
JUNE 2017

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GLOSSARY

Aqumada	sack made out of goat skin
Woreda	the third-level administrative divisions of Ethiopia
Gotera	local grain storage facility made of wood/ bamboo and mud
Quintal	a unit of weight equal to 100 kg
Thresh	separate grain (corn or other crops) from chaff typically with a flail or by the action of a revolving mechanism
Awdima	Amharic term for a field used for traditional threshing of cereals
Winnow	blow a current of air through (grain) in order to remove the chaff
Gota	a storage structure made from mud
Gotera	a storage structure made from wood sticks and plastered with mud
Nifro	food made after boiling beans
Shiro	food made our of roasted and grounded bean powder

LIST OF ACRONYMS AND ABBREVIATIONS

ACSI	Amhara Credit and Savings Institution
ADLI	Agricultural Development Led Industrialization
AMDe	Agribusiness and Market Development
ATA	Agricultural Transformation Agency
CLP	Critical Loss Point
CLPs	Critical Loss Points
CSA	Central Statistic Authority
ECX	Ethiopian Commodity Exchange
EIAR	Ethiopian Institute of Agricultural Research
ETB	Ethiopian Birr
FAO	Food and Agriculture Organization of the United Nations
FGD	Focus Group Discussion
FM	Frequency Modulation
FTC	Farmers Training Centres
GTP-I	Growth and Transformation Plan I
GTP-II	Growth and Transformation Plan II
IMF	International Monetary Fund
KII	Key Informant Interview
LLP	Low Loss Point
LLPs	Low Loss Point
MARC	Melkassa Agricultural Research Center
MoANR	Ministry of Agriculture and Natural Resources
NRM	Natural Resource Management
NTFP	Non-timber forest products
P4P	Purchase for progress
PASDEP	Plan for Accelerated and Sustained Development to End Poverty (PASDEP)
PH	Postharvest
PHL	Postharvest Loss
PHM	Postharvest management
PICS	Purdue Improved Crop Storage
SDA	Swedish Development Agency
SDC	Swiss Agency for Development Cooperation
SG	Sasakawa Global
SNNP	Southern Nations and Nationalities People
SNNP	Southern Nations Nationalities and People
USAID	United States Agency for International Development (USAID)
USD	United States Dollar
USDA	United States Department of Agriculture
WFP	World Food Program
WB	World Bank

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EXECUTIVE SUMMARY

Ethiopia has been renounced as a food insecure country for the last four decades. However, the postharvest loss has received little attention until recently, despite being one of the key factors that contribute to the food gaps in the country. This is in spite of earlier studies in the country having flagged that there is an unacceptably high loss of grains, which if saved, could contribute to ensuring food security in Ethiopia. Therefore, an in-depth study on the postharvest loss of grains in wider areas of Ethiopia and the associated contributing practices and factors, are required in in order to better understanding the current situation and develop a postharvest reduction program in the country.

Fourteen (14) woredas from Oromia, Amhara, SNNP, and Tigray regions were selected for the assessment of postharvest losses and postharvest management practices of maize, wheat, and sorghum and haricot bean. The selected woredas and crops were recommended by the Ministry of Agriculture and Natural Resources Management (MoANR) of the Federal Democratic Republic of Ethiopia under the ongoing project GCP/ETH/084/SWI "Reducing Food Losses through Improved Postharvest Management".

The postharvest loss (PHL) assessment was conducted using FAO methodology, which involves preliminary screening, survey, load tracking and sampling assessment and solution finding. Quantitative and qualitative loss assessments were made to identify the extent and types of food losses along the main food supply chains (FSC) of each commodity in the selected target woredas. The Critical Loss Points (CLPs) and Low Loss Points (LLPs) were identified in the selected food supply chains (FSC). A focus group discussion (FGD) was used to learn more about opinions, practices and problems of farmers in post-harvest management (PHM) and then to guide future action. Moreover, Key Informants Interviews (KIIs) were conducted in all the woredas with selected groups of experts involving crop protection, marketing/cooperative expert, agronomist, gender focal person, postharvest expert or representative, FAO focal person, agriculture extension, and Development Agents (DAs) from the two Kebeles. Field observations were made to better understand how crops were handled at different stages of FSC in each of the sample Kebeles.

Maize is Ethiopia's leading cereal crop in terms of production. Over half of Ethiopian farmers grow maize, mostly for subsistence. In 2013/2014, 8.8 million farmers produced 6.5 million tons of maize across 2 million hectares of land (CSA, 2014). PHL assessment of maize was conducted in three woredas: South Achefer (Amhara), Demba Gofa (SNNP), and Darimu (Oromia). The volume of maize production was 48889.6, 21257.8, and 75654.6 tons for Darimu, Demba Gofa and South Achefer with estimated Postharvest Loss (PHL) of 22.3, 23.1 and 19.3% respectively. The critical loss points of maize were identified to be at storage and harvesting points in decreasing order.

Ethiopia is the largest wheat producing country in Sub-Saharan Africa, with a potential expansion area of more than 1.4 million ha. Wheat is the fourth and third most important food crop in terms of production and productivity, respectively (CSA. 2009). The post-harvest loss assessment of wheat was conducted in four woredas; namely, Debre Elias (Amhara region), Gedeb Hasasa (Oromia), Soro (SNNP) and Ofla (Tigray). The total volume of wheat produced in the three woredas is 88,736.4; 41,029, 103,486.25 and 71428.8 tons per year respectively. The average post-harvest loss of wheat was 15.2, 14.2, 26.5 and 21 % in Debre Elias, Ofla and Gedeb Assasa and Soro woredas respectively. The critical loss points are at harvesting, threshing and storage points in increasing order.

Sorghum is one of the major staple crops grown in the poorest and most food-insecure regions of Ethiopia. The crop is produced under adverse conditions such as low input use and marginal lands (FAO, 2013). All of the sorghum produced in the country is used for domestic consumption and its contribution to food security is significant. Nearly 4.5 million smallholders located in the eastern and northwest parts of the country cultivate sorghum. The PHL assessment of sorghum was conducted in four woredas; Alamata (Tigray region), West Armachehu (Amhara region); Fedis (Oromia region), and Derashe (SNNP region). The total volume of sorghum produced in the four woredas was 86,400; 85,750, 395,928; and 71,428.8 tons per year respectively in Alamata, West Armacheho, Fadis, Derashe. The average yield is 4.8, 2.5 2.4 and 2.5 tons per ha respectively. The average post-harvest loss of Sorghum was 35.1%, 29.8%, 32.7% and 34.1% in Alamata, West Armacho, Derashe and Fedis respectively. The critical loss points are at harvesting, field stalking/drying, threshing/winnowing and storage points.

Among the twelve pulse species grown in the country, haricot bean is the second most produced after fava bean (36%), accounting for 17 percent of production (CSA, 2014). Haricot bean is predominantly grown in the warmer and lowland parts of the country. PHL assessment on haricot bean was conducted in three woredas; namely Tach Gayint (Amhara), Adami-Tullu-Gido Kombolcha (ATGK) (Oromia), and Lok Abaya (SNNP). The total volume of production of haricot bean per year for the study woredas was 7356.8, 14,062.4, 3982.1 tons per year, with average PHL of 12.2, 37.2 and 26.2 % for Tach Gaint, ATGK and Lok Ababay woredas respectively. The study identified harvesting, field drying and storage as Critical Loss Points (CLPs) for this crop.

In general, though the magnitude may vary, losses are unacceptably high for all four commodities studied in the 14 woredas visited. For the four woredas covered by the present study about 245,408 tons of food has been lost which can be extrapolated to 83.77 billion kcal of food. In monetary terms, the loss encountered could be close to 71.5 million USD. What is so painful is, merely because of our poor postharvest management and the loss encountered, the farmers did not benefit from their land which is closer to 68, 671 ha wasted which otherwise could have been used to produce other crops to feed so many malnourished people. Such losses are attributed to the poor postharvest practices of delayed harvesting, use of inappropriate threshing/shelling methods, poor storage condition of grains that render the crop vulnerable to damage by storage insect pests, rodents and contamination with mould. Farmers strive to prevent losses using indigenous practices such as the right time of harvesting (though unexpected rain is the common problem), cleaning of their storage, use of botanicals and other means.

To date, the institutional support given to farmers in reducing postharvest losses has been minimal or completely absent. The recent effort of FAO, together with the Ministry of Agriculture and Natural Resources (MoANR), in introducing metal silo storage and accompanied training given to farmers, Development Agents (DAs) and Artisans with regard to the use and construction of such storage is appreciable. Moreover, there is a very visible promotion work from SG2000 in order to enhance the use of postharvest technologies such as threshers and ’hermetic storage structures by farmers, service providers, cooperatives and Unions. However, since PHL management is a vertically and horizontally crosscutting issue, it is essential to coordinate the existing yet fragmented support of microfinance institutions, extension, NGOs, Private Service providers, and all other relevant stakeholders in order to bring meaningful support to farmers in their efforts to prevent substantial food loss after harvest.

Finally, yet importantly, the study has revealed that the extent of postharvest loss of grains in Ethiopia is alarmingly high. Major causes of postharvest losses and critical stages of intervention have been identified while improved handling and postharvest technologies are recommended. Therefore, a PHL reduction program should be launched as soon as possible, for which MoANR should setup institutional framework in order to mainstream and coordinate efforts of governmental and non-governmental institutions and prepare packages of Good Postharvest Practices for immediate implementation.

1. GENERAL INTRODUCTION

Food security remains one of the most pressing issues that demand our immediate attention. In addition to the limited food production, food loss after production has emerged as another major contributor to the persistence of food insecurity. One in every nine people on earth still has insufficient food for an active and healthy life (World Hunger and Poverty Facts and Statistics, 2013). The vast majority of these undernourished people live in developing countries, where an estimated 791 million were chronically hungry in 2012–14 (FAO, IFAD and WFP, 2014). People in developing countries often suffer losses of staple foods, mainly cereals, generally because of poor postharvest practices. The World Bank/FAO/NRI study (2011) estimated the value of losses at USD 1.6 billion per year (2005-07 prices) in East and Southern Africa. Extrapolating this estimate to all of Africa, losses could reach USD 4 billion, which is more than the average annual value of cereal imports for Africa.

It makes more sense and is economical to safeguard the crops that have been harvested instead of trying to make up for the losses through increases in production or imports. This indeed requires a good understanding the essence, extent and causes of postharvest losses before arriving at decisions on how to prevent them.

Quantitative (or physical) food losses refer to the decrease in edible food mass available for human consumption throughout the different segments of the supply chain. In addition to quantitative losses, food products can also face a deterioration of quality, leading to a loss of economic and nutritional value. Apart from the economic loss, in most cases, the quality deterioration goes along with a significant loss of nutritional value, and as such affects health and nutrition security of the population. The extent, type and causes of postharvest losses (PHLs) vary among countries and are strongly influenced by the nature of commodities and the stages of the specific supply chain in consideration in a given country.

Reducing postharvest losses, in addition to its contribution to food security, imparts significant effects on the environment, food quality and safety, and socio-economic development of a nation. In view of this, reduction of postharvest losses has been identified as economically advantageous and environmentally safe way to enhance food security. The first step in reducing PHLs is to uncover, in a systematic way, the main causes of the problem and then to design appropriate strategies for effective action. Therefore, it appears necessary to undertake a specific assessment of postharvest losses with due consideration of the different contexts. In this way, it would be possible to determine the extent and type of postharvest loss for the specific commodity in a particular region or place as the commodity or products move from the production site to the place of consumption; in short farm to fork/table.

Review of past works reveals that many researchers have attempted to assess postharvest losses of various crops in many countries of the world. Most of these studies were conducted at national level and were based on literature review, statistical data, and stakeholder interviews. Findings reported so far show different values of quantitative losses of food and contributing factors.

However, as elaborated by FAO (2014), “we don’t know yet which causes of food losses are the most important, what is the impact of solutions and which solutions are viable and cost-effective, in economic, environmental and food security terms. Meaning: the solution to food loss should not be more expensive than the food loss itself, should not place a higher burden on the environment and greenhouse gas emission, should make more food available to the people that need it most, and should be socially and culturally acceptable”.

In Ethiopia, different food crops are produced in unique agro-ecologies and seasons. This makes the task of identifying the main causes of postharvest losses challenging and hence necessitates the undertaking of specific studies that take into account these varying systems of production, postharvest handling and marketing among localities.

In view of the above facts, the present study was undertaken with the objective of determining the extent, types and causes of postharvest losses of maize, sorghum, wheat and haricot beans in the selected food supply chains (FSC) under fourteen target woredas of Ethiopia. Furthermore, the study assessed all potential measures (indigenous and available recommended ones) to reduce losses in respect of their technical and economic feasibility, social acceptability and environmental impact in an effort to develop a package of postharvest management practices to be adopted for food loss reduction programme.

2. METHODOLOGY OF THE STUDY

2.1 Assessment Methodology Adopted

The postharvest loss assessment investigated the extent and causes of postharvest grain losses of maize, sorghum, wheat and haricot bean in 14 woredas located in four different regions of Ethiopia shown in Figure 1 below.

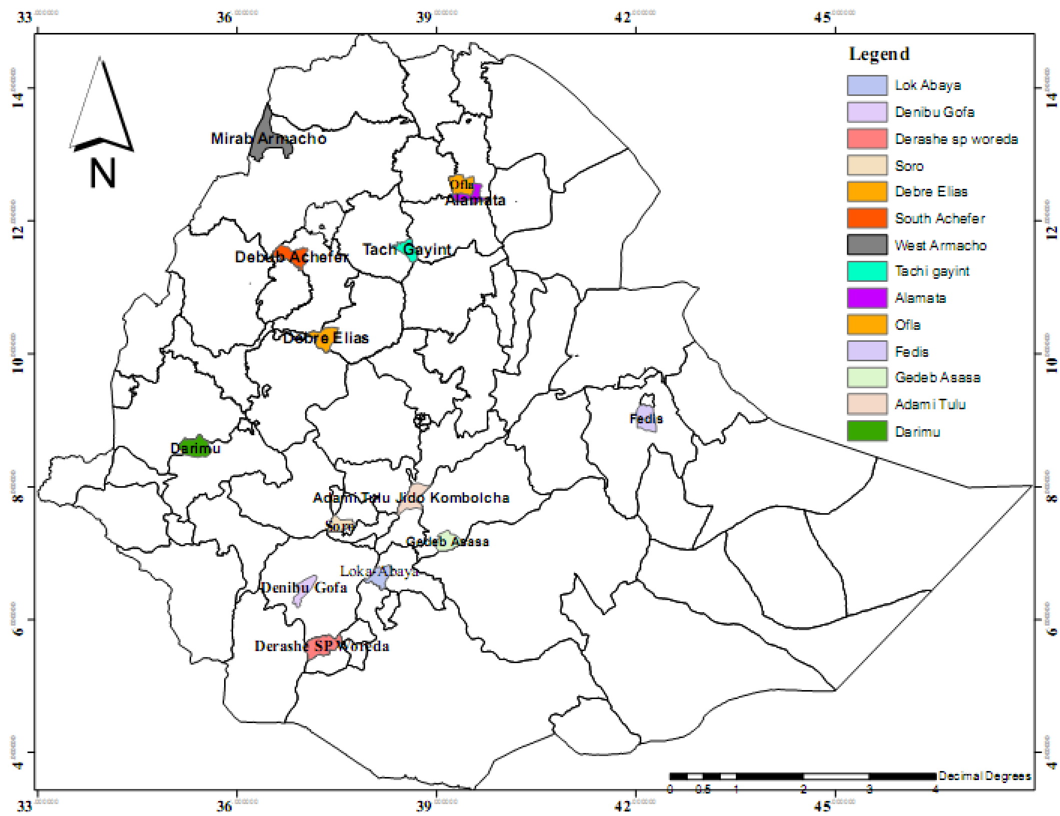


Figure 1. Map of Ethiopia showing the study woredas and regions

The study followed the important steps for postharvest loss assessment along the FSC in order to obtain a more valid data. The FAO methodology (Figure 2), which is a well-established approach having four steps ('4S'), was adopted. The steps include Preliminary Screening of Food Losses ('Screening'), Survey Food Loss Assessment ('Survey'), Load Tracking and Sampling Assessment ('Sampling') and Monitoring and Solution Finding ('Synthesis'). However, except load tracking and sampling was done only to some extend due to the limitations caused by the fact that 14 districts were involved.

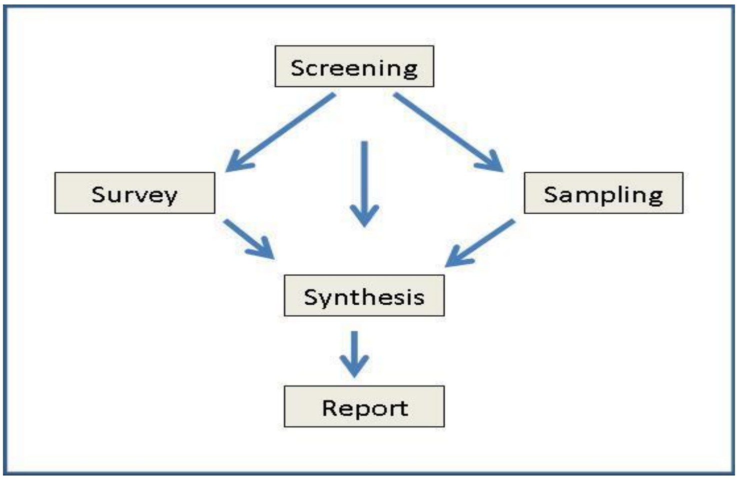


Figure 2. The four "S" elements of the FAO methodology of Postharvest Loss Assessment (Source: FAO, 2014)

Screening stage involved preliminary assessment of postharvest losses based on secondary data, documentation, reports and expert consultations without travelling to the study area (FAO, 2014). This enabled the team to collect as much information as possible prior to the field work. Moreover, reliance on literature review and secondary data analysis enabled the team to understand the situation in the target woredas and Kebeles (Table 1) with regard to the postharvest handling and losses of the selected commodities. The survey stage was initiated by making initial contacts with the FAO contact persons responsible for each of the study Woreda. This helped the consultants team to establish links, making it easier to identify experts from various institutions including the Development Agents (DAs) in the study Kebeles, farmers and other key informants for further survey studies. Quantitative and qualitative loss assessment was made to identify the main FSC of each commodity at target woreda. In the FSC, both CLPs (Critical Loss Points) and Low Loss Points (LLPs) were identified. CLPs and LLP are the points in the FSC where food losses have the highest and lowest magnitude, the highest and lowest impact on food security, and the highest and lowest effect implication on the economic aspect of the FSC, respectively for the specific commodity in the target woreda.

The major causes of losses at each stage and farmers management practices were noted for each commodity and target woreda. Moreover, information regarding demographic situation, area cultivated, volume and value of total production of the specific grain crop in the target woredas were documented. Most important FSCs and products in the target woredas were selected, based on literature review and consultation of different experts, for an in-depth study (Table 1). The team physically followed the product along the FSC, made direct observations and discussed with supply chain actors regarding the causes and solutions for losses. Finally, the team has suggested comprehensive grain loss reduction strategies for possible implementation.

Table 1. Grain crops, regions, zones, woredas and Kebeles selected for the study

Crops	Region	Zone	Target Woredas	Kebeles
Wheat	Amahara	East Gojam	Debre Elias	Chago & Guwayi
	Oromiya	West Arsi	Gedeb Assassa	Bucho & Huruba Walkite
	SNNP	Hadiya	Soro	Sundussa & Sigeda
	Tigray	South Tigray	Ofella	Selambeqalsi (wnbert) & Adigollo
Maize	Amahara	West Gojam	South Achefer	Akuri qeltafa & Abichikilli
	Oromiya	Illuababora	Darimu	Gobe & Odakama
	SNNP	Gamo Goffa	Denba Goffa	Sesga & Borda
Sorghum	Amahara	North Gondar	West Armacho	Abrajira1 & 2
	Oromiya	East Hararge	Fadis	Melka & Nega Umer Kulle
	SNNP	Segen Peoples	Derashe	Shelale & Onota
	Tigray	South Tigray	Alamata	Selambeqalsi & Kebele 07
Haricot beans (Dry)	Amahara	South Gondar	Tach Gaint	Anseta & Kebele 05
	Oromiya	East Shewa	Adamitulu	Halaku Gulanta Boke & Ananoo Shisho
	SNNP	Sidama	Loka-Abaya	Bartu & Argedo Haro Dimtu

2.2 Selected value chains

Fourteen woredas found under four administrative regions were selected to participate in the assessment. The Woredas and value chains were recommended by Ministry of Agriculture and Natural Resources (MoANR) of the Federal Democratic Republic of Ethiopia through the FAO project GCP/ETH/084/SWI "Reducing Food Losses through Improved Postharvest Management". The selected woredas are leading in the production of the crops selected under the value chains to be investigated. Two adjacent Kebeles were purposively selected from each woreda in consultation with officials and experts from the woreda agriculture office.

2.3 Tools and Data Collection Methods

2.3.1. Focus Group Discussions

A focus group discussion (FGD) was used to learn more about opinions, practices and problems of farmers in post-harvest management (PHM) and then to guide future action. Focus Group Discussions (FGD) were held in each woreda involving four farmers (2 male + 2 female) who were purposively selected from each study Kebele. Out of these four farmers, two were (1 male + 1 female) high producing model farmers and the remaining two (1 male and 1 female) were average producing farmers. Each focus group was composed of eight farmers (4M+4F) invited from two neighbouring Kebeles of the respective woredas making the total number of farmers that participated in the FGD in all the fourteen woredas to be 112.

The summary of the participants involved in the FDG and KII of the postharvest loss assessment is indicated in Table 2. During these FGDs the facilitator asked questions using the respective local languages and the farmers discussed and dialogued on the topic of discussions. Different local languages i.e. Oromiffa, Amharic and Tigregna, Sidamigna, Derashigna, Gofagna were used, with the help of translators. Both qualitative and quantitative data were collected pertaining post-harvest handling, causes and extent of post-harvest losses, consumption and marketing of the selected commodity in the respective woreda.

Table 2. Summary of participants involved in the FGD during the PHL assessment of four selected grain crops in 14 woredas of Ethiopia

Method	Respondents	Data collected	Number of farmers/ experts involved		Number of participants in each FGD/KII
			Men	Women	
FGD	Farmers	Production and productivity, harvesting, threshing, storage, consumption& marketing, transporting, gender roles in PHM, indication of the losses	56	56	6-10
KII	Experts	Production potential, volume, consumption, supply chains of the commodity, post-harvest loss, price data, post-harvest activities and technologies, gender roles	80	18	5-8

2.3.2. Key Informant Interview (KII)

The main purpose of the KII was to generate detailed information pertaining postharvest losses (causes, impacts and potential solutions), validate, and build on information from group interviews and observations, and provide case studies describing examples of the causes and effects of postharvest losses. Therefore, KIIs were conducted in all fourteen woredas with a selected group of key informants consisting of experts in crop protection, marketing/ cooperative, agronomy, postharvest, gender focal person or home management, FAO focal person, agriculture extension, and DAs from the two selected Kebeles of the respective woredas. Due consideration was given to the FAO methodology (FAO, 2015), relevance, knowledge and experience on postharvest handling and marketing of selected crops. Attempts were made to create and maintain diverse mixes of professionals and gender representation in relation to postharvest management practices of the crops as indicated in Table 3.

Table 3. Professional mix of key informants selected from each woreda for KII

No	Office	Assignment / Profession	Remark
1	Woreda Agriculture Bureau	Office head/vice head	Informant on overall postharvest handling practices, problems, opportunities and strategies, loss estimation
		FAO focal person	Informant on FAO activities in areas of postharvest practices, loss estimation
		Agronomist or plant science expert	Informant in relation to pre-harvest, harvesting and postharvest practices, loss estimation
		Pre and/or Postharvest crop expert	Informant on postharvest management practices, problems, loss estimation and efforts to reduce losses
		Gender focal person/expert	Informant to describe the role of women in postharvest management practices and processing, loss estimation
		Crop protection expert	Informant to describe field and storage related pests, loss estimation
		Agricultural extension expert	Informant to describe efforts (training, technology) have been done in areas of postharvest management practices, loss estimation
		Development agents of each Kebele	Informants to describe existing practices and experiences of farmers on postharvest management, indigenous practices and estimation of losses
2	Marketing /Coop	Cooperative marketing expert	Informant to describe supply chain of the crop, market outlet, role players in the market, price of the product, etc.

2.3.3. Field Observation

One of the major activities during data collection was observing the different postharvest activities along the supply chain. Though the study was conducted at a time when no harvesting practice was left, observations were made with regard to field storage/stacking, drying, shelling, threshing, transportation, storage and marketing in the selected woredas and Kebeles.

2.4 Methodology to Calculate Postharvest Losses

Quantitative postharvest loss of grains was estimated considering two stages of postharvest practices before and after storage of grains. Pre-storage PH practices included all practices from harvesting to final storage. The next phase focused on losses incurred during storage. In the first phase, percent PHL at each pre-storage stage was considered along with the potential yield to be harvested if there were no loss at each PH practice (detail calculation is indicated in Annex Table 1. However, the next phase or storage loss calculation considered losses out of net total yield obtained after threshing and winnowing/cleaning or from actual or net yield stored in the storage structure.

2.5 Cost-Benefit Analysis for Recommended Technologies

Following the identification of major causes and CLPs, relevant Postharvest technologies or strategies were put forward. In doing so cost-benefit analysis of each recommended technology was conducted using the variables indicated in Annex Table 2. When the profitability of a proposed solution was found positive, the recommended solution was considered economically feasible to use in order to achieve the anticipated PHL reduction.

2.6. Data Quality Assurance and Methods of Analysis

2.3.4. Validation

At the end of each FGD and KII, a 30 minutes validation meeting was organized to validate the results in the presence of FAO focal persons, postharvest experts, gender focal persons, cooperative marketing experts and heads of woreda agriculture offices. Participants of the validation meetings were asked to make their reflections on information including data that showed a significant discrepancy between FDG and KII.

2.3.5. Data Analysis

The audio files were transcribed according to Qualitative Data Preparation and Transcription Protocol proposed by McLellan et al. (2003)[1]. Written data, such as interview and field notes, were turned into findings using Qualitative Data Analysis (QDA). Among the different approaches of QDA, collaborative and participatory forms of analysis were employed. The research team also tried to involve others in the process and to discuss and review findings. Pictures taken during observations were also used in order to describe, elaborate and support qualitative data.

[1] http://fmx.sagepub.com/content/15/1/63.short?rss=1&ssource=mfr

3. FINDINGS ON POSTHARVEST LOSS ASSESSMENT

3.1 Postharvest loss assessment of Maize

3.1.1 Status and importance of maize

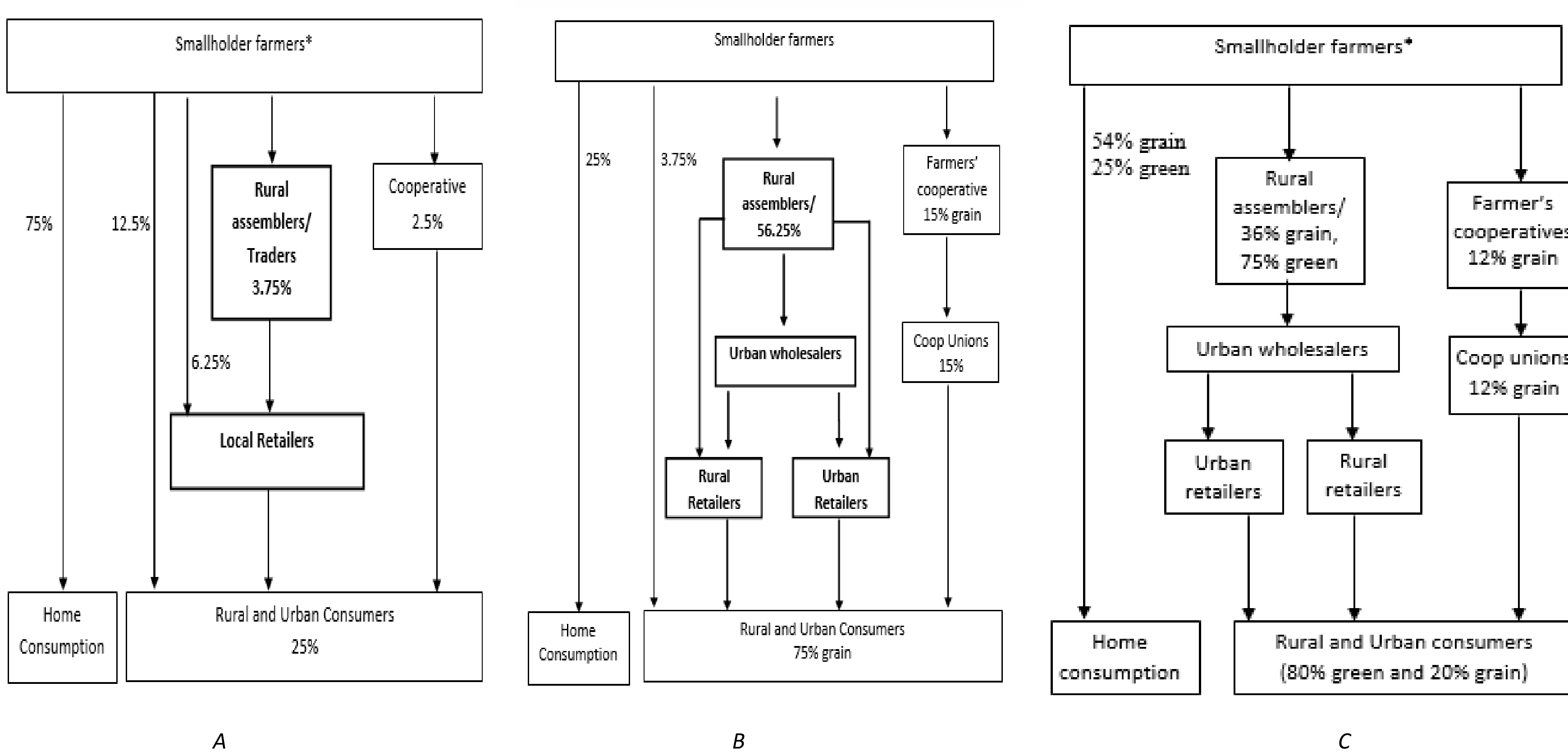
Maize is Ethiopia's leading cereal crop in terms of production. It is an important and cheapest caloric source among all major cereals (Demeke, 2012), providing 20.6% of per capita daily calorie intake nationally (IFPRI, 2010). Over half of Ethiopian farmers grow maize, mostly for subsistence. In 2013/2014, 8.8 million farmers produced 6.5 million tons of maize across 2 million hectares of land (CSA, 2014). Between 2000 and 2013, maize production doubled, due to increases in both per hectare yields and area under cultivation. It is reported that maize production expanded from 2.5 million tons in 2003/04 to 5 million tons in 2010/11 (Demeke, 2012) and to 6.5 million tons in 2013/2014 (CSA, 2014). Details of production status, productivity, the economic importance of the crop and product flow with actors involved in the three study woredas are indicated in Table 4 & Figure 3.

The study on postharvest loss assessment of maize was conducted in Darimu, Demba Gofa and South Achefer woredas in Amhara, Oromia and SNNP regions respectively where maize is the leading cereal crop. In Darimu woreda, maize production is the largest in terms of land coverage compared to other crops production. On the other hand, maize is the major crop in Demba Gofa and is produced during the short (Belg) and the main (Meher) production seasons. During "Belg" season maize is produced as a cash crop to be sold as green cobs, which fetches good price during this time of the year due to the high price of foods in the country just before the main rain season. Almost 80% of the maize produced in this woreda during the Belg season is supplied to different market outlets, while only 20% of the total harvest of dry grain harvested from Meher season is supplied to the market. Producers consider the former as a cash crop and the latter is grown mainly for home consumption. Both seasons have equal productivity and generate more than 0.8 million USD per annum.

In South-Achefer Woreda, only 25% of the harvested maize is consumed within the woreda. Maize production in South Achefer woreda increased annually on average 7% for the past 10 years. The calculated monetary value of maize for the woreda is around 15.68 million USD.

Table 4. Data on cultivated land, total production, consumption, and marketing of Maize at National and woreda level

National Maize									
Annual production (tons/yr) (average of 8 years 2003/04-2013/14)				**Cultivated area (ha) (average of 8 years 2003/04-2013/14)**			**Average yield (tons/ha) (average of 8 years 2003/04-2013/14)**		**Remark**
4,867,877.78				1,866,409.71			25.8		Average values of last 10 years **2003/04** to 2013/14 (Source: CSA Abstracts **2003/04**-2013/14)
Average annual growth for the last 8 years (%)									
2004/05	**2005/06**	**2006/07**	**2008/09**	**2009/10**	**20010/11**	**2011/12**	**2012/13**	**2013/14**	Calculated based upon CSA abstract from 2004 to 2014[2]
28.2	11.6	-0.7	4.6	-0.9	DNA**	35.8	1.4	5.1	
Average cost of production (USD/ton)									
121.0									Considering average cost of production of three studied woredas in 2015
Percentage for consumption, % PHL and % marketed in household level									Data calculated from average values of three woredas report of Darimu, Demba Gofa and South Achefer in 2015 (Maize grain).
Percent consumed			**Average PHL during storage of grain**			**Percent Marketed= Total -%PHL-% consumed**			
60			11.2			28.8			
Value of Marketed product # 1 maize(USD/year)									
8,263,824.1									This value is calculated from total production (Table 7) *Percent marketed*price of one ton of maize grain (196.8 USD)
Number and sex of Producers									Total number of producers of three woredas in the study area.
Male			**Female**				**Total**		
65,452			6015				15,031,435		
Levels of trading and processing operations									
			Small			**Medium**		**Large**	
Level Whole sale operation			-			*		-	
Level of retail operation			-			-		*	
Level of processing operations *			**NA**			**-**		**-**	



** The percentages indicate the proportion of maize produced and consumed by farmers, and proportion passed on to actors in the supply chain. The Thick arrows show the selected supply chain in the three study Woredas.*

*** negligible to quantify (only few farmers with large hectares sell to wholesalers)*

Figure 3. Actors and product flow in the maize supply chain in (A) Darimu, (B) South Achefer and (C) Demba Gofa woredas

3.1.2 Past and on-going interventions in maize loss reduction

There are no such interventions tailored specifically for maize but rather past and present initiatives are targeting reduction of postharvest losses of grain crops as a whole.

MoANR is responsible for formulating policies, initiatives and programs related to agriculture. Since 2014, it has been providing training on PHL reduction to development workers and farmers; however, data on the number of DAs and farmers trained is not readily available. It is striving to minimise post-harvest losses by working closely with other development partners such as SDC, USAID and NGOs.

FAO with the financial support from the Swiss Agency for Development and Cooperation (SDC) and in close collaboration with the Government of Ethiopia (GoE), is implementing a project GCP/ETH/084/SWI titled “Reducing Food Losses through Improved Post Harvest Management in Ethiopia” in 14 woredas. Among other things, the project is providing training and awareness creation on PHM and is promoting grain storage technologies like metal silos. Furthermore, the project has undertaken postharvest losses assessment study on four crops (haricot bean, maize, wheat, and sorghum).

USAID/Ethiopia’s Feed the Future (FtF) program has a plan to construct seven warehouses with a capacity of 5,000MT through its Agribusiness and Market Development (AMDe) project. The existing and planned warehouse capacity from USAID assistance is 55,000 MT, which will be a major contribution towards reducing postharvest losses of selected products such as wheat, maize, sesame and chick pea.

The World Food Program (WFP), through its ‘Purchase for Progress’ (P4P) program, began purchasing maize in 2013 from farmers’ cooperative unions on a contract basis and has planned to purchase 300,000 MT of maize from 50 cooperative unions in the year 2016. Additionally, it is providing technical support in postharvest handling and storage, to enable cooperatives to maintain the grain quality standards required by WFP.

The Rockefeller Foundation, USAID Ethiopia through its hybrid seed and postharvest storage program (USAID, Ethiopia and DuPont) has distributed improved composite maize seeds from 2013 to 2015 and increased access to improved postharvest storage facilities for 32,000 maize farmers in Ethiopia with the goal of increasing yields by 50% and reducing losses by 20%. President Barak Obama visited some beneficiary farmers during his official visit to Ethiopia last year.

SG2000-Ethiopia is another important player working on promotion of post-harvest technologies in the country. In 2010, it established Postharvest Extension Learning Platforms (PHELPs) at the Farmers training Centres (FTCs) of the three Kebeles, Enebi Chifar, Denkaka and the Semen Bellesa Kebele in Amhara, Oromia & SNNP Regions). The NGO has already introduced improved technologies including multi-crop threshers and shellers, a grain cleaner and harvester, improved grain silos, and the roller mills. Also, it helps to organize women agro-processing groups to add value to their produce and create market access for income generation. They have provided training in areas such as basic business skills, cooperative management, rice parboiling, grain postharvest handling and agro-business enterprise management and development, including warehouse management for a total of 624 newly identified and existing women’s AP groups, extension workers and farmers.

3.1.3 Policy Issues in Maize PHL Reduction

In Ethiopia, the policy has traditionally focused on production and marketing of food grains but components. So far, postharvest management issues have remained untouched. The past governments’ agricultural policy had never addressed postharvest issues as a strategic direction. Even agriculture and rural development policies of the current government have not adequately addressed the PHL reduction issues, addressing only production and productivity aspects. This can be observed from past policy documents on agriculture and rural development like the ADLI and GTP-I.

However, recently there have been promising actions taken which could influence the policy makers to consider PHM as one strategic direction of the nation's development process in general and food security initiative in particular. Some of the initiatives include: The establishment of the Ethiopian Postharvest Management Society (EPHMS) in 2016; establishment of the Ethiopian Postharvest Management Platform under the MoANR, formulation of postharvest research strategy by Ethiopian Institute of Agricultural Research (EIAR); the different donor agencies funding PHL reduction in Ethiopia and NGOs implementing PHL reduction activities including capacity building, pilot projects and financial services. The GOE is also worth mentioning for its intention to reduce postharvest losses by half by 2025 as stated in its GTP-II document. This is in line with the Malabo Declaration (2014).

3.1.4 Relevant Institutions and their Roles in PHL Reduction of Maize

There are international, national and regional, governmental and non-governmental institutions working on postharvest management activities in the maize sector. The role of these institutions ranges from small to medium intervention activities often focused on the production than postharvest aspects.

International institutions

Food and Agriculture Organization (FAO): FAO Ethiopia provides relevant post-harvest management training for farmers, Development Agents (DAs) in areas of PHM of maize. Melkassa Agricultural Research Center (MARC), with the financial support of FAO, gave training to Artisans on the construction of metal silos. Some of the institutions are involved in the provision of loan for the purchase of agricultural inputs and few others are supporting the marketing of the grain.

USAID: It has been supporting the MoANR by funding the Agriculture Growth Program (AGP). There are different initiatives in AGP among which the Feed the Future (FtF) Program and the Agribusiness and Market Development (AMDe) project are typically addressing the maize postharvest loss reduction interventions.

National and regional institutions

Ministry of Agriculture: The MoANR is mandated with the task of formulating the agriculture policies and strategies at different times. Through its organizational structures from Federal to Kebele levels, it formulates and implements agricultural policies, especially focusing on the production aspect.

Regional Bureau of Agriculture: The woreda agriculture office found in all regions provide broader services on production through its Farmers Training Centres (FTC), which are located in each Kebele. In most Kebeles, there are three DAs on each FTC. The DAs provide extension and advisory services for farmers. So far, the provided extension and advisory services focus mainly on solving production problems. Though the DAs and woreda experts give seasonal awareness creation on postharvest management activities for farmers, the PHM is not given significant emphasis.

Regional Microfinance Institutions: There are three regional microfinance institutions in the study woredas: Oromia Credit and Saving Share Company in Oromia regional state, Amhara Credit and Saving Association in Amhara region and Omo microfinance in SNNP region. These microfinance institutions provide financial services (both saving & credit) for their customers (men, women or youth) in any business including agriculture. They have their brunches in almost all woredas of their respective regions. Farmers are expected to organize themselves into small groups to obtain credit. This study found that the microfinance institutions have no special arrangement to support PHM activities and farmers in the study woreda do not request credit for PHM purposes. However, these institutions make agreements with farmers' cooperatives in each Kebeles and give credit facility for buying agricultural inputs (mainly maize seeds and fertilizer).

Farmers' cooperatives/cooperative unions: the woreda cooperative promotions offices work in organizing farmers into basic cooperatives and give training on the benefits of cooperative market vis-à-vis the conventional markets. However, there is no specific/strategic intervention on postharvest activities.

3.1.5 Overview of Maize Supply Chains

Owing to its high calorific contribution maize is one of the staple crops in Ethiopia with the greatest contribution to the national food and nutrition security followed by wheat (FAO, 2014; Demeke 2012). At the national level, the maize supply chain involves input suppliers, producers (dominated by smallholder farmers), traders (local assemblers and wholesalers), retailers, very few processors, and consumers. There is very limited linkage among the input suppliers, producers and traders.

The major input suppliers in Ethiopia include the Ethiopian Seed Enterprise (ESE), the Agricultural Input Supply Enterprise (AISE) and farmers' multipurpose cooperatives at a lower level. There are also sizable private traders at all levels who provide agro-chemicals and farm implements. Small-scale farmers are the key players in the maize supply chains in the study woredas in particular, and nationwide in general. Previous state farms have all been privatized but there are still few large private investors or farmers with of 5-10 hectares especially in the study woredas.

The supply chain for maize product involves diverse actors like the Ethiopian Grain Trade Enterprise (EGTE), the cooperative unions dispersed in all regional states, urban wholesalers, regional traders, local assemblers and farmers. In many cases, there are also brokers who act between the farmers and the regional traders at the local market level and between the regional traders and the central market wholesalers.

In the study woredas, maize is produced for the purposes of on-farm consumption and income generation. In the three study woredas, a total of 71,467 smallholder farmers produce an estimated annual production of 4,495,248.22 tons of dry grain and 76, 494,000 green cobs marketed as vegetables (Table 5). In all study woredas, maize is produced by smallholder farmers and is consumed by the poor, and thus has a higher contribution to the food consumption, food and nutrition security of the small smallholder (Table 6 and 7). From the three woredas, the economic importance of maize is higher for Demba Gofa where the farmers mainly depend on income from the sale of the green maize cob. About 25 and 75% of the maize produced in Darimu and South Achefer is marketed to improve the household income and leverage the living standard of the household.

Actors in the local market chain in the study woredas involve the smallholder farmers, village collectors, local assemblers and local or regional traders who either supply the national wholesalers or to the regional retailers. Farmers use pack animals like donkey or horse cart, or own labour (carrying sacks) to transport their grain to the nearest local market. They may also sell to rural assemblers, mostly independent operators at primary markets, who assemble and transport the grain using pack animal and small trucks for sale in urban markets (Rashid and Negassa, 2011).

Table 5. Maize supply chains, volume of production, number of farmers and market outlets for Darimu, Demba Gofa and South Achefer woredas in Ethiopia

FSC Maize	Geographical area of production	Final product	Volume of final product (tons/year)	Number & sex of smallholder producers	Market of final product, location, buyers	Project support
1	Darimu	Maize grain	48,889.62	F=1977 M=27440	Dupha, Addis Ababa, Adama	SDC, FAO
2	Demba Gofa	Maize grain	21257.8	F=375 M=15477	Sodo, Hawasa, Shashemene, Addis Ababa (central market)	FAO
		Green cobs in number	76, 494,000			
3	South Achefer	Maize grain	75,654.60	F=3663 M=22535	Gonder, Bahirdar, Mekelle and Weldia	FAO ATA

Table 6. Importance of maize supply chains at national level

FSC # (Woreda)	Economic Importance	Generation of foreign exchange	Contribution to national food consumption	Contribution to national nutrition	Environmental impact	**Total score**
1. Darimu	1	NA	3	3	1	**9**
2. Demba Gofa	3	NA	3	3	1	**11**
3. South Achefer	1	NA	3	3	1	**10**

* *1= Low 2 = Medium 3= High*

Table 7. Importance of maize supply chains for its actors

FSC #	%age of produce by smallholders	Income generation	Involvement of the poor	Employment Provision	TOTAL SCORE Table 7+Table 8
1	3	1	3	1	**18**
2	3	3	3	1	**21**
3	3	2	3	1	**19**

* *1= Low 2 = Medium 3= High*

Postharvest losses occurring along the maize supply chains are indicated in Figure 1 above. Overall, a sizeable amount of postharvest loss occurs at each of the postharvest activities along the maize supply chain, which include; harvesting, transportation, cob drying, cob storage, threshing/shelling and grain storage. The CLPs and LLPs at major postharvest activities, which contributes to the PHLs of maize are indicated in Table 8 below. The survey conducted in the study woredas and available literature indicated that at each step of the postharvest activities, there are losses but the steps at which CLPs and LLPs occur vary across the study woredas.

Table 8. Preliminary screening of losses in the selected maize supply chain

Step in the FSC	Expected loss Points: Quantitative CLP or LLP	Expected loss Points: Qualitative CLP or LLP	Comments/ Remarks
Main Maize FSC Darimu Woreda			
Harvesting	LLP	LLP	Hurry during harvesting
Transportation to Threshing site	LLP	LLP	Poor transportation practice
Maize cob Drying	LLP	LLP	Damage by termites, pests and rain
Storage of maize cob	**CLP**	LLP	Storage pests
Threshing/shelling	LLP	**CLP**	Hurry and poor practice during shelling
Grain storage	**CLP**	LLP	Storage pests and migration of moisture
Main Maize FSC Demba Gofa Woreda			
Harvesting	LLP	LLP	Hurry during harvesting
Field drying (temporary storage)	**CLP**	LLP	Poor transportation practice
Removing sheath from cob	LLP	LLP	Damage by termites, weevil and rain
Transportation and temporary storage around the house	LLP	LLP	Storage pests
Shelling and winnowing	LLP	CLP	Hurry during harvesting
Storage (with or without cob)	**CLP**	LLP	Storage pests and migration of moisture
Main Maize FSC South Achefer Woreda			
Harvesting	LLP	LLP	Hurry during harvesting
Field storage and Drying	LLP	LLP	Poor transportation practice
Transportation to Threshing site	LLP	LLP	Damage by termites, pests and rain
Threshing/shelling & winnowing	**CLP**	**CLP**	Hurry during harvesting
Storage	**CLP**	LLP	Storage pests

3.1.6 Main supply chain of maize- situation analysis

3.1.6.1 Description of the major supply chain

The major maize supply chain actors in Ethiopia include producers (mainly smallholder farmers in this case), rural assemblers, (private) wholesalers, retailers (rural and urban) and consumers.

Producers (smallholder farmers)

Smallholder farmers contribute more than 90% of the national maize production mainly producing maize for their own home consumption for subsistence with the surplus maize being marketed, which is nationally estimated as 95%. Farmers sell most of their produce within three months after harvest as they fear storage loss (will be described in detail latter in this paper) and to meet various cash needs including repayment of loans, payment of taxes and to cover miscellaneous expenses (based on survey).

The field study in the three study woredas indicates that maize producers have different market outlets including rural assemblers/certified and uncertified traders, rural retailers, rural and urban consumers and farmers' cooperatives. The percentage share of each market chain actors is different for each woredas as shown in Figure 3. The main supply chains of maize identified include the following:

(i) Producer to consumer

One of the major maize supply chains in the study woredas is the direct supply from producers to urban/rural consumers. Urban consumers, in this case, indicate the woreda towns where farmers can directly sell their product to the consumers. Farmers in all three woredas are able to sell maize grain at the local open market. The place and dates of the local markets vary across woredas but usually, the woreda capitals serve as the main centre for local markets.

(ii) Producer → retailer → consumers

Retailers play an important role in delivering maize to the final consumers of both rural and urban areas. The majority of the retailers are small scale unlicensed traders who buy the product directly from smallholder farmers at a cheaper price and handle the product for less than a week in most cases. They sell the product at slightly higher prices to the consumers. The percentage of the product marketed by retailers varies among the three study woredas; 6.25% in Darimu, 8% in Demba Gofa and 20.20% in South Achefer of which 12.20% is through urban retailers and the remaining 8.0% is via rural retailers.

(iii) Producer → Local traders → Wholesalers → Retailers → consumers

Maize is also bought by local and regional certified and registered wholesaler traders. These traders buy maize from/through rural assemblers. The rural assemblers collect maize from the smallholder producers at the local market or by going from one village level markets to another. They normally operate independently assembling and transporting maize by pack animals and small trucks to the nearest urban markets where there are medium-sized licensed traders. The licensed traders keep the product in their store before transport it to the central market.

The wholesalers are mostly regionally or nationally licensed grain traders. They collect maize from the traders/rural assemblers and store it. There are different types of wholesaler like those at regional market, central market and those at surplus production areas and deficit or non-producing areas.

The study indicates that the percentage of maize marketed through the wholesalers is 3.7%, 36% and 36.05% for Darimu, Demba Gofa and South Achefer woredas respectively. Maize is taken to Gondar, Bahir Dar and Mekelle from south Achefer woreda; Dupha and Mettu from Darimu woreda and Addis Ababa, Adama, Hawassa and Shashemene from Demba Gofa woreda (Table 5).

(iv) Producers → rural cooperatives/cooperatives Unions → consumers

Rural farmers' cooperatives also buy maize from farmers, usually, the farmers are members of the cooperative, but the cooperative may also buy it from non-members. The rural farmers' cooperatives are found in each woreda.

3.1.6.2. Description of the existing marketing systems

As indicated earlier, although smallholder farmers indicated that maize is primarily produced by smallholders for subsistence, a sizable proportion of the produced maize is marketed (Figure 3-5). The field research in the study woredas indicated that marketing of maize is done seasonally depending on the agro-ecological conditions, that determine the production system and the form of the product marketed.

Proportion of the product marketed

In all study woredas, the smallholders primarily produce maize for consumption though the surplus is marketed in order to obtain the cash needed by farmers for their household use. The proportion of maize supplied to the market varies considerably among woredas. It was noted during the study that most of the green maize produced in Demba Gofa woreda is sold as green maize cobs 'Eshet' (Table 9).

There are two production seasons in Demba Gofa, '*Belg*'- the small and '*Meher*'-the main rainy seasons. The former is mainly vegetable (green cob), what is locally called 'eshet', in order to generate cash while the harvest from the latter is used for a dried maize grain. Out of the total maize production in the '*Belg* season' (76,494,000 cobs per a woreda/year), 80% is marketed and 20% is consumed. From the total *Meher* production in the woreda (21,257.28 tons/year), only 20 % is marketed and the rest 80% is consumed at home. In Darimu woreda, the proportion of maize consumed and marketed is 75% and 25% respectively while in South Achefer the proportion is 25% and 70% respectively for dried grain the remaining 5% being marketed as green cobs.

Table 9. Products in Maize Supply Chain in Darimu, Demba Gofa and South Achefer woredas of Ethiopia

Process	**Duration**	**Product out**	**Weight from 100**	**Conversion Factor**
Darimu Woreda				
Harvesting	2 days	Maize ear	100	1
Field drying	2 weeks	Maize cob	90	1.11
Transportation	2 days	Maize cob	90	1.11
Storage	3-6months	Maize cob	90	1.11
Threshing/shelling	Varies	Maize grain	60	1.67
Storage	1-3months	Maize grain	60	1.67
Demba Gofa Woreda				
Harvesting	2 days	Maize ear	100	1
Field drying	2-3 months	Maize ear	100	1.11
Removing cob sheath	2 days	Maize cob	90	1.11
Transportation	<3 days	Maize cob	90	1.11
Threshing/shelling	6 days	Maize grain	58	1.72
Storage		Maize grain	58	1.72
South Achefer Woreda				
Harvesting	2 days	Maize cob	100	1
Field drying	2 weeks	Maize cob	90	1.11
Transportation	2 days	Maize cob	90	1.11
Storage	3 months	Maize cob	90	1.11
Threshing /shelling	2-3 days	Maize grain	60	1.67
Transportation	1day	Maize grain	60	1.67
Storage	6months	Maize grain	60	1.67

Market place and mode of transport

Market place for maize is diversified; in some instances (example marketing of maize green cobs), it starts at the farm gate in the village where producers sell the product at their farm gate. In most cases, the market place of the smallholder producers is located at certain village centres and capitals of each woreda. There are open markets at village centres and woreda town where farmers transport their grains for selling to consumers or assemblers. Farmers may also take the product to the certified traders who have their own places mostly around their store in woreda towns.

In all study woredas, women are the ones mainly involved in taking the product to the market. Donkeys are the major mode of transport for maize and other products but if the family does not own a donkey, the women will carry the maize on their backs. Assemblers move from Kebele to Kebele buying maize, sometimes moving maize from the three woredas to the central market in Addis Ababa and other regional cities like Gondar, Dessie, Adama, Shashemene, Sodo and Harar.

In the case of the green maize from Demba Gofa woreda, brokers are the major market actors linking farmers with other green maize traders. Prices are determined through negotiations considering existing the existing market prices but highly influenced by brokers in favour of the buyers. After the agreement, buyers are responsible for the collection of cobs and therefore they only collect good cobs that fit to preferences at destination markets. If there is no access to road, farmers use donkeys to transport cobs to the place where vehicles can reach. Purchased cobs are either transported to nearby markets (larger towns like Sodo and Shashemene) or to central market depending upon the price of green cob and transportation cost.

The market chain, form of product and price

The market chain for the green cobs is mainly from producers to wholesalers (through assemblers and brokers), from producers to retailers and direct chain from producers to consumers, which represents the local urban population. As for dried maize grain, there are different market chains, including a direct sale to consumers, retailers, wholesalers and cooperatives. Details of the major SC of maize in Darimu, Demba Gofa and South Achefer woredas of Ethiopia are indicated in Figure 4.

The market shares of each chain actor are 50% direct sale to consumers, 25% to retailers, 15% to wholesalers, and 10% to cooperatives in Darimu; 30% direct to consumers, 10% to retailers, 45% to wholesalers, and 15% to cooperatives in Demba Gofa; and 75%, 20%, and 5% were purchased by traders, cooperatives and local consumers respectively in South Achefer woreda.

The price of maize in all study woredas varies across seasons of the year and with the form of product marketed. In Darimu woreda, maize is marketed mainly in a dried whole grain form. The average price per 100kg (calculated from 2014/15 year monthly price) was 374.16 Birr (USD18.25). The maximum price for a 100kg of maize in the woreda market, for the production year 2014/15, was 550 Birr (USD26.83) which happened in the months of July and August; while the minimum price was 250 Birr (USD12.2) which lasted from September to November. In Demba Gofa, the average price per 100kg for the dried maize grain was 421.25 birr (USD20.55). The maximum price received for a 100kg of maize on the woreda market (in the production year 2014/15) was 550 birr (USD26.83) which happened in the months of May and June, but the minimum price was 325 Birr (USD15.85) from September to December. For the green maize, the price is fixed and it is one birr per cob. However, if the cobs are small the price may be halved. In South Achefer the average price for dried grains ranges between 280 and 550 Birr (1US = 21Birr in August 2015). The price shocks happen most often due to the absence of contractual selling or processing firms and shortage of storage facilities necessary for extending storage of grains in the world woreda.

Market information

In all study woredas, producers' market information access is very poor. Lack of sufficient market information was mentioned as one of the major problems for the farmers. Although farmers mentioned access to sources of market information like TV, radio, and cell phones, they would benefit from an organized market information service at woreda level. For this, they depend on daily information that they get from the local market itself.

Major market problems in the study woredas

The following major market problems were identified in the three woredas studied:

- Lack of sufficient market information for farmers: There are no reliable market information or organized exchange systems. Therefore, in this case, buyers and sellers have to bargain and negotiate to arrive at mutually agreed prices. However, owing to unequal information, and since farmers are price takers / they tend to be taken advantage of the market.
- Poor storage facilities: owing to lack of affordable and adequate storage facilities, farmers cannot store their grains and wait for higher prices later in the season.
- The interference from brokers/small aggregators who stand between farmers and the buyers. These brokers get more benefit and sometimes they cut up to 100Birr per 100kg. This is the benefit could have gone to the farmers, had there been a proper functioning market or a well-developed value chain. Rather in such non-functioning market system, limited and poorly developed infrastructure to support the proper movement of harvests to the nearby markets favours the existence of more brokers/small aggregators as farmers do not have the capacity to move their produce to the market place for it is not profitable to pay for their small volume of produce.
- Lack of bargaining capacity and price negotiation skill by farmers: As mentioned above, buyers and sellers have to bargain and negotiate to arrive at mutually agreed prices. However, farmers who are organized in cooperatives do have the high bargaining power to get better profit margins than individual farmers that do have less market information as well has a limited volume of production and unsustainable supply to consumers.

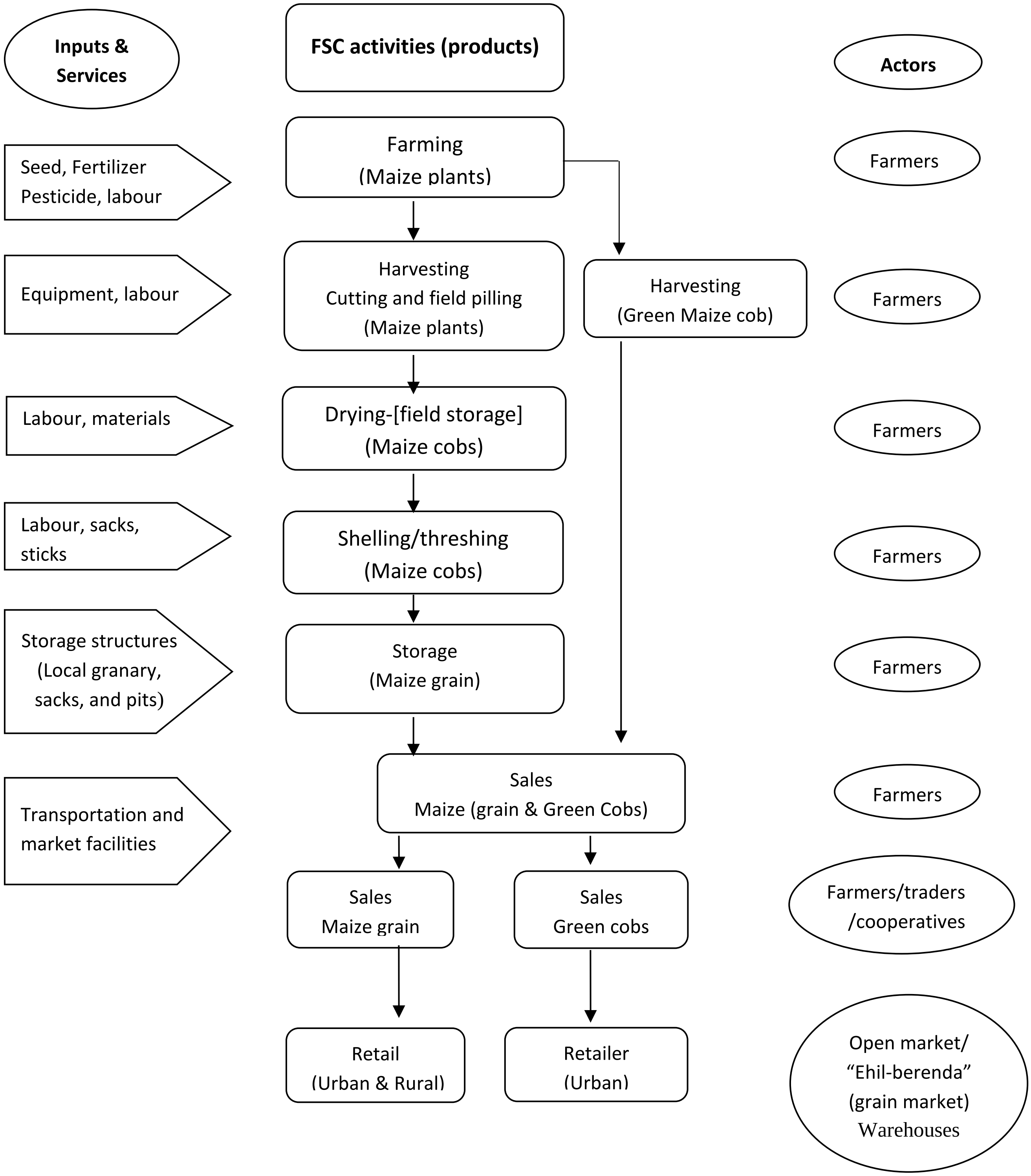


Figure 4. Flow diagram of the major maize supply chain in Darminu, Demba Gofa & South Achefer woredas of Ethiopia

3.1.2.1 Gender Roles in PHM

Maize production and postharvest management are farm activities done by family labour, where both men and women play distinct roles. Rural women in Ethiopia represent a tremendous productive force in the agricultural sector, and PHM activities are no exception.

The present study found that women participate in each stage of the FSC and PHM activities. They participate in constructing *gota/gotera* (in south Achefer woreda), harvesting, transporting, shelling and winnowing, storing the grain, and taking the grain to market. Figure 5 clearly depicts the involvement of women in important postharvest activities. They also take part in making the decision on the proportion of the product to be used for household consumption and marketing. Additionally, women are the sole actors in processing maize into different forms of maize product to be consumed or marketed. On the other hand, men play the leading role in threshing, applying pesticides to the grain for pest control and making decisions on the expenditure of the income from sales leaving women without any say on the way the income obtained is spent.

Participation of men and women at each stage of the FSC was measured in percentage as shown in Table 10 below. Accordingly, the role of women (82.8%) exceeds that of men (68.7%). However, this does not indicate the benefit gained by women from the return. During the separate focus group discussion with women, in all the three studied woredas, more than 85% of the women reflected that sale of maize is decided jointly but men control the income.

Table 10. Detailed description of the Maize supply chain – social structures (Roles of gender in production and postharvest activities)

FSC STEPS	Women			Men			Gender / social patterns Additional observations and remarks
	D	DG	SA	D	DG	SA	
Primary Production	2	2	2	2	2	2	Men are dominantly in charge of land preparation, fertilizers and pesticides application.
Harvest	2	2	3	2	2	3	Men and women participate weeding and harvesting. Children also participate.
Stocking and drying	2	2	2	3	3	2	Both women and men are involved
Storage	2	2	2	2	2	2	Both women and men are involved
Transportation	3	3	3	3	3	3	Men and women participate
Market sales	3	3	2	2	2	3	Traditionally dominated by women at local markets for small sales, men decide when big volumes are involved.
Agro-processing	3	3	3	1	1	1	Female-dominated because taking grains to mill is the gender role of females.
Storage	2	2	3	3	3	1	Varies across regions, but both men and women participate.
Transportation	3	3	3	1	1	1	Female-dominated this stage because of gender role of women (small sales), but men are in charge when long distances commercial vehicles are involved.
Wholesale	3	1	2	3	3	3	Dominated by men who deal with buyers at this level
Retail	3	3	3	1	1	1	Traditionally dominated by women in local markets, but dominated by men when wholesale is involved.
Total scores	**28**	**26**	**28**	**23**	**23**	**22**	
% participation	**84.8**	**78.8**	**84.8**	**69.7**	**69.7**	**66.7**	

D= Darimu, DG=Demba Gofa and SA=South Achefer. Gender roles in FSC are rated from 1 to 3 where: 1= low, 2= medium and 3= high

Figure 5. In addition to their reproductive and social roles, women are involved in pre-and postharvest activities of maize

3.1.3 PHL of maize- study findings

3.1.3.1 Maize Loss Risk Factors

Maize suffers from a number of postharvest loss risk factors. Maize post-harvest loss refers to the loss of grains (quality and quantity) between the stages of harvest and consumption. Maize losses occur at all stages of the post-harvest handling practices, including harvesting practice, (field) drying, shelling and winnowing, transportation, storage, processing, packaging and marketing. All loss risk factors recorded in the study woredas are presented in Table 11 below.

Table 11. Maize loss risk factors in Darimu, Demba Gofa and South Achefer woredas of Ethiopia

Variable	**Unit**	**Parameter: Relation to food losses - contributing to low losses**	**Value of variable (observed in the case study)**		
			D	**DG**	**SA**
Crop (improved variety)	Maize	Resistant variety to storage pests	N	N	N
Good Agricultural Practices (GAP)	Y/N	Yes	N	N	N
Rainfall during Production	Y/N	Optimum range	Y	Y	Y
Production supply/ demand ratio	Ratio	< 1	>1	>1	>1
Rainfall during Postharvest phase	L/M/H	Low rainfall			
Postharvest technology	L/M/H	High	L	L	L
POs / Coops	Y/N	Yes	Y	Y	Y
Processing technology	L/M/H	High	L	L	L
Good Manufacturing Practices (GMP)	Y/N	Yes	N	N	N
Packaging materials and facilities	L/M/H	High	L	L	L
Cold chains	Y/N	Yes	N	N	N
Transport duration	Hour	Low duration (< 1h)	1-2	1-3	1-2
Market information	L/M/H	High	L	L	L
Price incentive for quality	Y/N	Yes	N	N	N
Knowledge of FSC actors	L/M/H	High	L	L	L
Consumer access to food product	L/M/H	High	L	L	L

Legend: Y/N = yes / no; L/M/H = low / medium / high; D= Darimu, DG=Demba Gofa, SA= South Achefer

3.1.3.2 Observed PHLs and Critical Loss Points (CLPs)

This part presents the type and level of maize PHLs observed during the maize postharvest handling activities along the supply chains in the three study woredas. It presents both qualitative and quantitative losses and the identified CLPs for the supply chain. Detailed information of the observed PHL and CLPs for the three woredas is presented in Table 9.

Harvesting

Maize harvesting by smallholder farmers in the study woredas is done manually by using two different methods. The first method involves hand mowing of the maize with its half-stalk or the cob with small stalk using sickles. The second method of maize harvesting is undertaken by removing the ears by hand.

Harvesting of dry maize is initiated when the plant has well matured. The maturity of maize is determined by farmers based on observable physical and physiological factors such as: dry leaves, dry seeds, drooping of the head, dry stalks, the easiness of removing seeds from the cobs while shelling, and time the crop has stayed in the field. The cob of maize bends and hangs downwards as a natural sign of readiness of the crop for harvest. If the maize head is still up, it is an indication that the optimum moisture content for harvest is not yet reached. In some years, there might be rain during harvest, which causes a problem as water gets in through the cob and the grains germinate and develop mould.

The occurrence of an intermittent rain during harvesting may hinder the harvesting operation and initiate mould development on the maize head where the sheath is removed by birds. Such maize cobs may become infected by moulds, leading to post-harvest losses. Moreover, maize that is planted late is characterized by poor grain filling, invites more birds and cutworms damage, while early-planted maize can be more infested by weevils leading to a poor harvest.

Loss of Maize grain starts at harvest and continues along the supply chain but the amount of loss depends on the rain, handling by the farmers, insect pests and domestic animals damage
In all study woredas, there is no modern technology to overcome the losses encountered during harvesting. However, farmers try to minimize losses by collecting the cobs lost while cutting, tightening of the cob head with maize sheath to prevent entrance of rain, protecting from damage by birds, and use of tolerant varieties. On the overall, farmers' practices towards loss reduction include proper handling and follow-up to collect all cobs from their farms.

Drying
Maize drying includes temporary field storage of cobs with stalk by piling or the maize ear drying after it is transported to the threshing place (Figure 6). In most cases, immediately after collection of the cobs at one place in the field, they are transported and spread on a threshing floor located close to the homestead for drying, which takes about 15 days depending on weather conditions. The main causes of losses observed during the drying of maize cobs on the threshing floor may include; domestic animals, infestation by termites and weevils, or infection by mould caused to maize grains. Details could be found in Table 12-14.

Figure 6. Field drying of maize with its stalks in Alamata area

Transport
Different cycles of transportation are involved in the different stages of the maize supply chain. These include transportation of harvested maize cobs to field drying, transportations of dried cobs to the threshing place, transportation of the shelled and winnowed grain storage site and finally transportation of the grain to the market or processing place. Animals or trucks are means of transport and grain is normally transported in bags.

Threshing/shelling and winnowing
Maize cobs are removed from storage (Gombissa/gotera) and subjected to shelling/threshing when needed for home consumption or for selling. Traditionally, shelling is performed in two ways: by pressing with the thumb against individual cob stalk and by putting cobs in a bag and beating with a stick.

Hand shelling is tiresome and painful but results in no qualitative and quantitative loss. However, beating maize cobs in sacks with sticks is relatively faster and more efficient than hand shelling but will result in some physical damage, which makes grains more vulnerable to pests and moulds and damage to the germ. Manual winnowing is commonly done at the place of threshing which reduces postharvest loss using a wooden spade for separating the grain from the chaff (Figure 7). Due to these common practices, a loss estimated during shelling and winnowing is relatively low. The use of mobile or stationary small-scale maize shelling machines was not observed. However, in the year 2015/16, development agents and farmers from selected villages were trained on PHM practices and technologies for storage and shelling through FAO support.

Figure 7. A wooden spade used to separate grain from chaff by tossing against the wind

A wide plate made locally from a grass called *sefed* is used to remove debris from maize grains by winnowing. Winnowing a lot of maize grains by hand is an arduous operation but leads to negligible quantitative loss. The extent of loss during shelling/threshing and winnowing of maize vary from woreda to woreda as indicated in Table. 12-14. The estimated losses are 0.8, 1.0 and 6.25% for Darimu, Demba Gofa and South Achefer woredas respectively.

Storage
There are different practices used for maize storage in the study woredas. Farmers store dry maize cobs in *Gotera/gombisa* if they want to store for more months. In this case, dried maize cobs are stored in local storage structures called *'gotera'* in Amharic *or 'Gombisa'* in Afan Oromo, which is made of thin woods and covered with mud or cow dung form inside. Alternatively, after shelling and winnowing, farmers store maize in polypropylene or jute bags of 50 or 100 kg capacity. Although *Gotera* is normally made from wood and plastered with mud and cow dung, farmers in Alamata woreda use stones to build their *gotera* (Figure 8). In some areas, farmers also use traditional underground 'pit' storage. Pit storage is mainly practised in some lowland villages of Darimu woreda.

Marketing: Visit to the central market in Addis and other regions revealed that losses due to damage by rodents, insects and birds are less than 1%. Loses are dependent on the duration of stay for the product before sale. Traders employ household pets (e.g. cats) to control rodents and at times use rodenticides like “commando”. They also apply chemicals such as phostoxin and actellic to control storage insect pests.

Small-scale processing: The result of a short load tracking during flour milling in Jimma close to Darimu woreda revealed that there is almost 1.58% loss due activities related to cleaning, milling and sieving (Annex 2). This is much lower than what has been observed for wheat and sorghum (4.58 and 5.07%, respectively). Moreover, this value is relatively small (half) than what has been reported in Kenya (FAO, 2014).

Figure 8. Where wood is very scarce to use for construction of outside grain stores farmers use stones and mud to build their gotera

The main causes of storage loss are from rodents, weevils, animals, theft, grain rot caused by rain and mould development. For both cob and grain, storage pests (weevil) and rodents take the larger share of storage loss which can be estimated to account for more than 75% of loss during grain storage. In the case of cob storage, if the top of the storage structure, *gotera*, is not covered carefully, the effect of rain is also high. Storage of maize grain is one of the important critical loss point (CLP) which needs maximum attention to minimize postharvest losses. The loss at this stage is caused by rodents, insects especially weevil, mould, domestic and wild animals and theft, but storage insects (Weevils) and rodents are the most serious ones.

In order to minimize storage losses, farmers are also using few modern techniques although traditional methods are still dominant. The modern methods include the use of chemicals for control of storage pests and improved storage structures. The chemicals that are commonly used in the study woredas are Malathion and Actellic 2% which are supplied by local traders. Often times farmers store grains in containers or without inside their leaving rooms (Figure 9) and the use chemicals under such circumstances could be unsafe Farmers reported that they have not received training on efficient application and safety aspects. Some of the improved storage structures mentioned are modified *Gotera* which is made on the raised structure and has an iron sheet cover on the top and rat baffle made of conical iron sheet fitted to stands of the *Gotera* to protect rodents from climbing and inside to the storage structure.

Figure 9. Small-scale producers do not have a separate room to store the grains with or without containers.

Critical Loss Points (CLPs)

Very importantly, in all of the study woredas, most losses occur during storage making it an important CLP for maize. It was estimated that PHL losses during maize storage were 11.5%, 12% and 10% for Darimu, Demba Gofa and South Achefer woredas respectively, making storage an important stage.

Storage loss can be either loss of the cobs in local garner or maize grain stored in sacks. These two CLPs need immediate intervention to minimize such huge loss. The other CLPs in the maize supply chain include harvesting and field drying stages for Demba Gofa woreda and shelling and winnowing stages for South Achefer woreda. Though it is not rated as CLP, harvesting is also very important in Darimu woreda.

Reduction of such huge losses at each stage of the FSC will not only ensure food security at household level but will also significantly improve the income of farmers and contributes to the national economy at large. Therefore, all actors in the FSC need to consider these points.

Table 12. Summary Result Matrix of Food Losses for Maize in Darimu Woreda

FSC stage/ process	Type of loss QN/QL	% lost in this process QN	% product that incurred QL loss in this process	% product that goes through this stage	% loss in the FSC	Cause of loss/ Reason for low loss	Reduced market value	CLP / LLP	Destination of food loss	Impact/ FSC actors affected (men / women)	Loss perception of FSC actors (men / women)	Suggested solutions	
Harvesting	**QN**	1.0		100	1.0	Appropriate harvest time		LLP	Consumption Consumption	Farmers	Income	Farmers are not conscious of loss at these stages	- Training farmers on FSC - Establish post-harvest extension - Follow up of extension by experts' group
	QL		**0.4**		0.4	Careful handling	0.4						
Transportation	QN	0.4		98.6	0.4	Care, nature of crop		LLP	Consumption Local beer/ feed/ discarded/	Farmers	Income		
	QL		0		0	Insects pest, rodents, mould	0						
Drying	QN	2.4		98.2	2.4	Done in sacks or on canvas		LLP	Consumption	Farmers	Income		
	QL		0.3		0.3		0.3						
Storage of maize cobs	QN	3		95.5	3	Appropriate harvest time		LLP	Consumption Consumption	Farmers	Income	Farmers have perceived loss at these stages with less understanding of impacts	- Scaling up of good PH handling practices - Training farmers on affordable & available improved storage technologies - Strengthening farmers' cooperative in PHM activities -Empowering farmers for PTD in PHT
	QL		1.5		1.5	Careful handling	1.5						
Threshing/ Shelling & winnowing	QN	0.6		91.0	0.6	Care, nature of crop		LLP	Consumption Local beer/ feed/ discarded/	Farmers	Income		
	QL		**0.2**		0.2	Insects pest, rodents, mould	0.2						
Grain maize Storage	QN	9.3		89.2	9.3	Done in sacks or on canvas		CLP	Consumption	Farmers	Income		
	QL		**2.1**		2.1		2.1						
Marketing and consumption	QN	Negligible	Negligible	77.7	-								
	QL												

Table 13. Summary Result Matrix of Food Losses for Maize in Demba Gofa Woreda

FSC stage/ process	Type of loss QN/QL	%age lost in this process /QN/	% of the product incurred QL in this process	% of product goes through this stage	% loss in the FSC	Cause of loss/ Reason for low loss	Reduced market value (%)	CLP / LLP	Destination of QL food loss (discard, consumption, sale)	FSC actors affected (men/ women)	Impact of PHL at the FSC	Loss perception of FSC actors (men/ women)	Suggested solutions
Harvesting	QN	2.4		100	2.4	Leftover during stocking, eaten by animals,		CLP	Consumption	Farmers	Income	Farmers are not conscious of loss at these stages	- Train farmers on FSC - Establish post-harvest extension - Follow up of extension by experts' group - Scale up of good PH handling practices, - Train farmers on affordable and available improved storage technologies, - Strengthen farmers' cooperative in PHM activities, - Empower farmers for PTD in PHT
	QL		0.5		0.5		0.5						
Field drying/ temporary storage	QN	3.5		97.1	3.5	Termite, animals, Decaying, discolouration		CLP	Consumption	Farmers	Income		
	QL		1.3		1.3		2.3						
Removing cob sheath	QN	0		92..3	0	Careful handling,		LLP	Consumption	Farmers	-		
	QL		0		0		0						
Storage maize cob	QN	1.9		92.3	2.4	Careful handling		LLP	Consumption	Farmers	Income	Farmers have Perceived loss at these Stages with less understanding of impacts	
	QL		0.5		1.9		0.5						
Shelling & winnowing	QN	1		89.9	1	Done in sacks or on canvas		LLP	Consumption	Farmers	Income		
	QL		0		0		0						
Storage maize grain	QN	9.2		88.9	9.2	Insect pests, rodents, mould & rotten grain		CLP	Discard or animals feed	Farmers	Income		
	QL		2.8		2.8		4.8						
Local Marketing & consumption	QN	Negligible		76.9	-	-		-	-	-	-	-	-
	QL		Negligible		-		-						

*percent market price reduced assumed that equivalent to percent PHL (QN+QL), *percent market price reduced assumed that equivalent to percent PHL (QN+QL)

Table 14. Summary Result Matrix of Food Losses for Maize in South Achefer Woreda

FSC stage/ process	Type of loss QN/QL	%age lost in this process (QN)	% of the product incurred QL in this process	% of product goes through this stage	% loss in the FSC	Cause of loss/ Reason for low loss	Reduced market value (%)	CLP / LLP	Destination of QL food loss (discard, consumption, sale)	FSC actors affected (men / women)	Impact of PHL at the FSC	Loss perception of FSC actors (men/women)	Suggested solutions
Harvesting	QN	0.75		100	0.75	Appropriate harvesting time, no rain		LLP	Consumption	Farmers	-	Farmers are not conscious of loss at these stages	- Train farmers on FSC - Establish post-harvest extension structure - Follow up of extension by experts' group
	QL		0		0		0						
Drying/field storage	QN	1.8		99.25	1.8	Discoloration		LLP	Consumption	Farmers	Income		
	QL		0.7		0.7		0.7						
Transportation	QN	0.25		96.75	0.25	Careful handling		LLP	Consumption	Farmers	-	farmers have perceived loss at these stages with less understanding of impacts,	- Scale up of good PH handling practices - Train farmers on affordable and available improved storage technologies - Strengthen farmers' cooperative in PHM activities - Empower farmers for PTD in PHT
	QL		0		0		0						
Threshing/ Shelling and winnowing	QN	4.75		96.5	4.75	Poor facility/ materials, broken grains		CLP	Consumption	Farmers	Income		
	QL		1.5		1.5		1.5						
Storage maize grain	QN	7.5		90.25	7.5	Insect pests, rodents, mould, rotten grain		CLP	Local market/ feed /discarded	Farmers	Income		
	QL		2.5		2.5		2.5						
Local Marketing& consumption	QN	Negligible		80.25	-	-		-			-		
	QL		Negligible		-		-						

*percent market price reduced assumed that equivalent to percent PHL (QN+QL)

3.1.3.3 Causes of Losses and Identified Loss Reduction Measures

PHL in maize can be both qualitative and quantitative as observed during the fieldwork of this study. Losses occur at different stages of the FSC and are caused by several factors. These causes can be classified into basic, underlying and immediate causes as shown in Annex Figure 1.

Each cause of loss is associated with symptoms and types of losses. The basic causes of maize PHL are associated with macro issues like the absence of supporting policies for PHM, poor infrastructures, shortage of trained human power in the area and low economic capacity of the country. The underlying causes are related to the absence of PHM service providers, lack of/shortage of postharvest technologies, lack of awareness of farmers about the use available services and technologies and lack or limited PH extension services and market information. The cumulative effects of the above causes will lead to the immediate cause of postharvest loses of maize in terms of physical, chemical, biological and cultural dimensions. Each of the dimension of losses is then observed in the FSC.

3.1.3.4 Low Loss Points (LLPs) and Good Practices

Low loss points (LLPs) in the FSC in the study woredas (Table 12-14) show that the stage of FSC at which LLPs occur differs among to woredas and from one stage to the other. Notably, there are some good practices in each woreda. For example, while transportation loss contributes a significant percentage of the loss calculation in Darimu and South Achefer woredas, transportation loss in Demba Gofa loss is almost nil because of farmers' maximum care during transportation. Similarly, while harvesting loss accounts for more than 3.5% of the total loss in Darimu and Demba Gofa woredas, it is less than 1% in South Achefer woreda. This is mainly because farmers in South Achefer woreda selectively harvest maize cobs with stalks and allow them to dry in order to avoid mould formation at storage.

On the other hand, while in Darimu and Demba Gofa threshing/shelling contributes less than 1% loss (LLP) in Darimu and Demba Gofa woredas, it is a CLP in South Achefer woreda contributing to 4.5% of the total food loss. This is because farmers in the two woredas use sacks or canvas for threshing with maximum care but South Achefer farmers use poor facility/materials while shelling or threshing of maize.

Pit storage, though it is tiresome and sometimes risky, also helped farmers to control storage pests and store their grain for more than six months, which is not possible if maize is stored in sacks at home. Another good practice, which has minimized storage loss, is the practice of storing maize with its cobs than threshing and storing the grains. One reason for this could be the mechanical damage caused to grains during threshing which renders the kernels more susceptible to damage by insects. Another reason could be the ease of movement of insects in threshed maize than in cobs.

3.1.4 Maize loss reduction strategy-Conclusions and recommendations

3.1.4.1 Impact of Maize Losses

According to FAO, the issue of food losses is of high importance in the efforts to combat hunger, raise incomes and improve food security in the world's poorest countries (FAO, 2011). The issue of maize PHL is not simply a matter of creating awareness on the importance of PHM activities but it can also be approached from the viewpoint of an economic activity for employment, value addition, income linkages, and environmental and socio-cultural significance.

Impact on nutrition and food security

Nutrition and food security are currently the main global challenges, the issue of malnutrition in both developed and developing countries being particularly alarming (Horton, et al., 2008). As it is indicated in the introduction part of this report, maize is a very important cereal crop in Ethiopia serving as a staple for many people. In studied woredas, the estimated PHL losses of maize in terms caloric value are 39.8M, 17.9M, and 53.2M kcal for Darimu, Demba Gofa and South Achefer Districts respectively (Table 16). In terms of per capita, the annual loss could be estimated as 1352.96, 1129.20 and 2030.69 Kcal respectively. Therefore, any intervention that minimizes PHL could have a meaningful contribution to the national as well as household food and nutrition security.

Impact on Economy

PHL in maize can impart a significant economic loss to the FSC actors and the nation at large. Table 15 below indicates the calculated PHL of maize and its expression in monetary value for the three study woredas. On average, the postharvest losses in these woredas was **22,421.02** tons /year, which is equivalent to 4.4. million USD for the three woredas in total.

Table 15. Economic and caloric value impact of PHL of Maize in three Woredas of Ethiopia

Woreda	Percent weighted loss (%)	Total production (tons/year)	Weighted loss (tons/year)	Price of grain per ton per woreda	Loss in Monetary Value (USD/yr)	Productivity of crop (tons/ha)	Loss of cultivated land (ha) due to PHL	Caloric value loss (kcal/yr) Billion
Darimu	16.00	48,889.60	7,828.10	182.50	1,428,629.74	3.10	2,525.20	2.86
Demba Gofa	17.10	21,257.80	3,635.00	205.50	746,992.25	4.40	826.10	1.33
South Achefer	14.50	75,656.6 0	10,957.90	202.40	2,217,881.55	6.70	1,635.50	4.00
Total	**15.90**	**145804.00**	**22,421.02**	**196.80**	**4,393,503.54**	**-**	**4,986.84**	**8.20**
Mean	**15.90**	**-**	**7,473.67**	**196.80**	**1,464,501.18**	**4.70**	**1,662.28**	**2.70**

* During study time the exchange rate for 1 USD = 20.5 ETB (Ethiopian Birr);**price was calculated from average price of months in 2015,

* There are 365 calories in 100 grams of whole wheat flour (Marquart et al., 2008)

Deforestation, CO_2 emission and environmental impact

PHL of maize has implications on the environment and utilization of natural resources. The land required to produce the estimated **22,421.02** tons of maize lost due to poor PHM is **4,986.84** ha. This land is therefore simply wasted. If this amount of land necessitates clearing forest, then one can think of the opportunity costs forgone such as amount CO_2, which would have been sequestered, the volume of soil and water conserved or the number of biological fauna and flora inhabited in the forest. Above all, forestlands could serve in the fight against climate change or help to promote income generation through provision of forest and Non-timber forest products (NTFPs) to the community or attraction of agricultural tourism.

3.1.4.2 Required inputs and cost-benefit analysis of maize loss reduction measures

Among several postharvest activities of maize in the study woredas, storage of grains is identified as the major CLPs. As indicated in Tables 12-14, estimated losses during storage were 16%, 14.4% and 10% percent in Darimu, Demba Gofa and South Achefer woredas respectively. Accordingly, storage is considered the CLP for the maize supply chain and hence, improved storage structures like hermetic containers are recommended. Several makes of hermetic bags such as PICS, GrainPro, ZeroFly and A to Z are commercially available. Cost-benefit analysis (Annex Table 3) for the bags showed a positive profitability of 13.2 USD/yr to achieve 95% reduction of losses during storage. However, use of galvanized metal silo resulted in negative (Annex Table 4) profitability for the same goal of loss reduction during storage. This is mainly associated with a high production cost of the storage structure (219.5 USD/metal silo for one-ton capacity) and the current low price of maize (169.8 USD/ton) in the national market. However, with a reduced production cost of metal silos (145 USD) and better market price (342 USD/ton in 2013), the use of metal silo could be profitable. In addition, investment in a maize thresher/sheller for individual purposes may not pay off. However, cooperatives and unions could install multi-crop threshers and provide service to member and non-member farmers for reasonable service charge. Individual service providers could also purchase multi-crop threshers with financial arrangements from credit and saving institutions and could recover the cost within few years by collecting service charges from farmers. This has proven very successful in many maize producing areas in Ethiopia including Shashemene and Arsi Negele areas.

3.1.4.3 Maize Loss Reduction Plans and Strategy

A well thought, carefully planned and coordinated PHL reduction strategy is needed for Ethiopia. The loss reduction strategies should consider the CLPs along the maize FSC. Accordingly, the following interventions have been identified.

- *Organizing regular training programs* with specific aim of creating awareness among the different stakeholders regarding the extent, causes and mitigation strategies pertaining to postharvest losses
- *Development of efficient maize value chains* for major producing areas in the country to trim off the middlemen that are reaping the biggest share of the margin with little or no value addition. This requires proper mapping of the existing supply chain and the major actors and develop an efficient value chain that can benefit those actors that create or add value with better profit margins without compromising consumer satisfaction.
- *Encouraging the design and development of affordable and appropriate technologies* for harvesting, drying, threshing and storage through sustainable funding of research budget for University and Research Centers. These may include the use of cribs, mechanical threshers, metal silos, etc. that have proven cost-effective and efficient elsewhere.
- *The GoE should devise a mechanism of reducing costs* for cost hermetic storage systems such as hermetic bags and metal silos, which have been proven to protect grains, beans and pulses from moisture, insects and oxygen during storage. Therefore, the supply of these storage materials on time and at an affordable price is essential to significantly reduce losses.
- *Encouraging Financial arrangement*: As it is being done for pre-harvest activities, credit and saving institutions, microfinances and other governmental and non-governmental banking institutions should also show their commitments in making special credit arrangements to support farmers in the purchase postharvest technologies on a lease basis.

3.1.4.4 Follow-up Action Plan

The immediate intervention required to reduce postharvest of maize is effective training in order to create awareness at all levels ranging from officials involved in policy drafting and implementation to village level development agents. A national platform should also be established and capacitated to oversee postharvest related activities in terms of provision of training, research activities as well as coordinating stakeholders who are directly or indirectly involved in the postharvest subsector. Absence of policy framework and/or strategy to support postharvest activities in the country is another bottleneck contributing to the occurrence of a significant amount of losses. Universities, EIAR, MoANR, ATA, farmers, traders as well as processors should work in collaboration to develop and provide inputs for the preparation of relevant policy frame to minimize postharvest losses for the benefit of the country. Farmers Training Centres (FTC) should be well organized and equipped to address postharvest issues in addition to the existing focus given to pre-harvest activities. Technical and Vocational Training Colleges should address postharvest issues in their curricula with required knowledge and skill. Eventually, the current one-to-five peer group at the lower administrative levels can be used as a good platform to create awareness, conduct training and disseminate available postharvest technologies to mitigate the postharvest loss of maize and other agricultural products.

3.2 Postharvest loss assessment of wheat

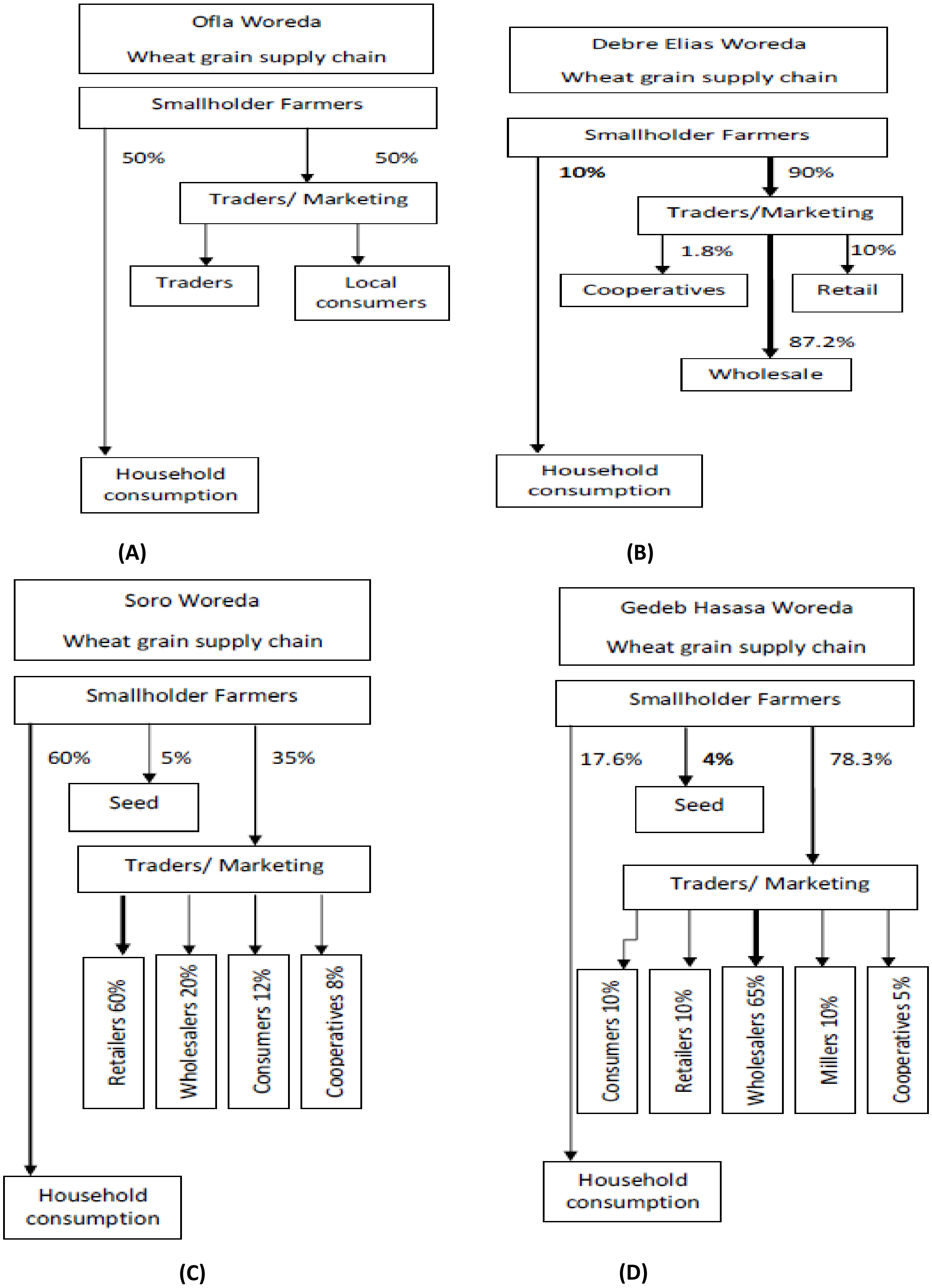
3.2.1. Status and importance of wheat in Ethiopia

Ethiopia is the largest wheat producer in Sub-Saharan Africa, with annual average durum and bread wheat production of 2,537,639.8 tons on about 1.4million hectares. Predominantly grown by subsistence farmers under rain-fed conditions, wheat is the 4th and 3rd most important food crop in terms of production (2,537,639.8 tons) and productivity (1.75 tons per hectare), respectively (CSA, 2009). Wheat is one of the major staple crops in the country and in terms of caloric intake; it is the second most important food in the country next to maize (FAO, 2014). Regardless of all this, Ethiopia is reliant on foreign wheat imports to satisfy its annual domestic demand (AGP, 2016).

Wheat production zones in Ethiopia lay 6^{o} and 16^{o} North, and 35^{o} and 42^{o} East, at altitudes ranging from 1500m to 3000m (Takele, 2015). The most suitable areas for wheat production, however, fall between 1900m and 2700m in the highlands where rainfall distribution is bimodal and ranges between 600mm and 2000mm. The rainy season in these areas is divided into the short rains (*Belg*) falling from March to May and the main rains (*Meher*) falling from June to August. According to White et al (2001), bread wheat and durum wheat account for roughly 60% and 40%of the total wheat production, respectively with emmer wheat contributing a small proportion.

Oromia accounts for over half of national wheat production (54 %), followed by Amhara (32 %); SNNP (9 %); and Tigray (7 %) (CSA, 2014). Woredas selected for this assessment were Debre Elias (Amhara), Ofla (Tigray), Gedeb Hasasa (Oromiya) and Soro (SNNP). The total area cultivated, total production and mean productivity of wheat in these woredas are explained in Table 16.

About 90% of wheat in Debre Elias is produced for marketing and the remaining 10% is meant for home consumption. In this woreda, wheat goes through different channels shown in Figure 10: 1.8% through cooperatives, 87.2% through wholesalers, and 10% through retailers. Marketing is directly managed by both male and female farmers (but men have more control) and minimal involvement of brokers. From the total produce of wheat in Ofla woreda, about 50% was sold while the rest was consumed at home. Wheat produced in Gedeb Hasasa Woreda is used for consumption (17.6%), seed (4%) and market (78.3%). The market shares of each chain actor are 10% direct to consumers, 10% to retailers, 65% to wholesalers, 10% to milling industry and 5% to cooperatives (Figure 10). In Soro Woreda, though the major proportion of the wheat is consumed (60%), a significant proportion (35%) of the grain is supplied to local and nearby markets, while the remaining 5% is used as a seed for next production season (Figure 10).



**The percentages indicate the proportion of wheat produced and consumed by farmers, and proportion passed on to actors in the supply chain. The Thick arrows show the selected supply chain in the study Woreda.*

Figure 10. Actors and product flow in the wheat supply chain in following woredas: (A) Ofal, (B) Debre Elias, (C) Soro and (D) Gedeb Hasasa

According to USDA data, overall wheat production from 1990 to 2007 increased five times and area harvested by more than two times. The annual growth rate of production for the time period indicated was 14.1 percent whereas area cultivated grew by 8.2 percent annually. The last seven years (2001-2007) had a continuous increase in the production with an increase in total area harvested. During these seven years period, production almost doubled and areas harvested almost increased by 25 percent. Furthermore, average production was 2,761,429 metric tons and average area harvested was 1,809.14 hectares. However, during 1990 to 2000 average wheat production was 1,313,727 metric tons and average area harvested was 1,174.73 hectares (ECEA, 2008). Therefore, the postharvest management of the crop deserves due attention.

3.2.2 Past and on-going interventions in wheat loss reduction

3.2.2.1 Use of machinery in in postharvest operations for wheat

Agricultural mechanization is not new to the Ethiopian agriculture since it has been in use in Arsi region as early as 1969 during the start of Chilalo Agricultural Development Unit (CADU). Farmers in this region were interested in mechanical threshing due to the initial promotion of agricultural machinery (Jonsson, 1972, cited in Hassena et al, 2000). However, elsewhere in the same region as well as other parts of the country, wheat postharvest handling operations from harvesting to storage are still labour intensive being mainly done manually. However, nowadays in major wheat growing areas like Arsi, Bale and West Gojam zones, wheat is harvested using combine harvester being operated on hire service arrangement. Particularly in Hassasa and Eteya district, the majority of farmers prefer to use combine harvester for harvesting and threshing of their crop unless there are topographic limitation or unavailability of harvesting machinery. Apart from the use of tractors, combine harvester and trucks for transportation, there are no any other improved harvesting and storage structures used in these specific regions.

3.2.2.2. Policy issues in wheat PHL reduction

Consider policy related issues pertaining PHL reduction of wheat, Ethiopia lacks a clear postharvest related policy for agricultural products in general and wheat in particular. Ethiopia's Agricultural Development Led Industrialization (ADLI) was launched in 1991 in cooperation with the World Bank (WB) and International Monetary Fund (IMF). This long-term strategy aimed to transform the economic structure of the country in a shift from subsistence to commercial agriculture for the growth of industry and services (Desalegn, 2008).

Table 16. National and woreda levels data on cultivated land, total production, consumption, and marketing of Wheat

<table>
<tr><td colspan="10">National Wheat</td></tr>
<tr><td colspan="3">Annual production (tons/yr) (average of 8 years 2003/04-2013/14)</td><td colspan="3">Cultivated area (ha) (average of 8 years 2003/04-2013/14)</td><td colspan="3">Average yield (tons/ha) (average of 8 years 2003/04-2013/14)</td><td>Remark</td></tr>
<tr><td colspan="3">2,860,765.6</td><td colspan="3">1,520,793.0</td><td colspan="3">1.87</td><td>Average values of last 10 years 2003/04 to 2013/14 (CSA Abstracts 2003/04-2013/14)</td></tr>
<tr><td colspan="10">Average annual growth for the last 8 years (%)</td></tr>
<tr><td>2004/05</td><td>2005/06</td><td>2006/07</td><td>2008/09</td><td>2009/10</td><td>20010/11</td><td>2011/12</td><td>2012/13</td><td>2013/14</td><td rowspan="2">Calculated based upon CSA abstract from 2004 to 2014</td></tr>
<tr><td>1.9</td><td>9.9</td><td>-6.4</td><td>8.8</td><td>17.5</td><td>DNA**</td><td>-5.5</td><td>15.1</td><td>12.5</td></tr>
<tr><td colspan="10">Average cost of production (USD/Ton)</td></tr>
<tr><td colspan="9">274.09</td><td>Considering average cost of production of three studied woredas in 2015</td></tr>
<tr><td colspan="9">Percentage for consumption, % PHL and % marketed in household level</td><td rowspan="4">Data calculated from average values of three woredas report of Darimu, Demba Gofa and South Achefer in 2015 (Maize grain)</td></tr>
<tr><td colspan="2">Percent consumed</td><td colspan="3">Average PHL during storage of grain</td><td colspan="4">Percent Marketed= Total -%PHL-% consumed</td></tr>
<tr><td colspan="2">45.9</td><td colspan="3">6.6</td><td colspan="4">47.5</td></tr>
<tr><td colspan="9">Value of Marketed product # 1 wheat(USD/year)</td></tr>
<tr><td colspan="9">54,472,563.8</td><td>This value is calculated from total production * Percent Marketed *price of one ton of maize grain (376.3 USD)</td></tr>
<tr><td colspan="9">Number and sex of Producers</td><td>Total number of producers of three woredas in the study area as indicated in Table 17</td></tr>
<tr><td colspan="3">Male</td><td colspan="3">Female</td><td colspan="3">Total</td><td rowspan="2"></td></tr>
<tr><td colspan="3">67,486</td><td colspan="3">21043</td><td colspan="3">88,529</td></tr>
<tr><td colspan="9">Levels of trading and processing operations</td><td></td></tr>
<tr><td colspan="3"></td><td colspan="2">Small</td><td colspan="2">Medium</td><td colspan="2">Large</td><td></td></tr>
<tr><td colspan="3">Level of whole sale operation</td><td colspan="2">-</td><td colspan="2">*</td><td colspan="2">-</td><td></td></tr>
<tr><td colspan="3">Level of retail operation</td><td colspan="2">-</td><td colspan="2">-</td><td colspan="2">*</td><td></td></tr>
<tr><td colspan="3">Level of processing operations</td><td colspan="2">NA</td><td colspan="2">-</td><td colspan="2">-</td><td></td></tr>
</table>

The ADLI strategy considers small-scale farmers and local government administrations as the two key players in achieving its policy goals mainly focusing on pre-harvest activities. In order to fulfil this development goal of ADLI, two 5-year plans have been implemented. The first one is a Plan for Accelerated and Sustained Development to End Poverty (PASDEP) 2005/06 to 2009/10. The postharvest issue under this plan was only briefly mentioned under the pest control section considering only storage structures and storage pest as a major postharvest problem. In its section 7.1.6b, it says that *"Appropriate training will be given to pest-control personnel and farmers. Methods for postharvest loss management will be developed and disseminated through extension packages to promote improved storage structures and practices."* (FDRE, 2006). However, the scope of postharvest management is beyond the use of improved storage structures and control of storage pests. The second 5 year plan was to implement Growth and Transformation Plan I (GTP-I) from 2010/11-2014/15. GTP-I also gave due attention to produce enough food for domestic supply and high-value crops for export with much attention through the use of improved pre-harvest activities. GTP-I underpins three important strategic areas for forge agricultural growth in the country namely: i) increasing productivity of smallholder farmers; ii) improving Natural Resource Management (NRM) and promoting irrigation, and iii) increasing participation of smallholder farmers in agricultural marketing and production of high-value crops. Postharvest loss reduction and value addition aspects were given minor emphasis or obscured under other topics in the plan. Therefore, in the past, no specific, clear and standing policy and strategy was developed and implemented on post-harvest management areas. However, in GTP-II, there is a plan of reducing PHL by half (Following Malabo declaration, 2014), and there are strategies vivid enough to bring about this intended change.

3.2.2.3. Relevant Institutions and their roles in PHL reduction of Wheat

There are several institutions supporting the postharvest management (PHM) of wheat in the study woredas (Appendix Table 4 to 8). For example in Debre Elias, ATA has facilitated the use of multi-crop threshers; FAO and MARC have jointly trained farmers, DAs and youth artisans on the use and construction of metal silos; private service providers provide combine harvester rental service with a fixed rate of 90 ETB per 100kg. However, there were no finance institutions supporting PHM of wheat. ATA and Private investors are also providing service in terms of creating farmers' access to combine harvesters. However, much more needs to be done in promoting appropriate postharvest management practices in the woreda.

On the other hand, Ofla woreda has many supporting institutions in place. However, the contribution of these institutions in reducing postharvest losses or promoting good postharvest management of grains is surprisingly low. So far, only FAO in collaboration with MARC has provided training for artisans, DAs and farmers on construction and use of metal silo, respectively. Like Debre Elias, access to finance and credit for postharvest undertakings is non-existent in Ofla. ATA has introduced combine harvesters in the area for harvesting and threshing and yet a sizeable number of growers are still harvesting and threshing their wheat manually and/or threshing by animal trampling. The combine harvesters have been introduced very recently and farmers are less aware of their benefits owing to the limited promotion of the service provision related to these machines. Moreover, there is a limited capacity of the local people to purchase the combiners.

In Gedeb Hassasa, several institutions were found to be supporting the wheat subsector mainly on pre-harvest activities. Micro-finances lend money only to farmers organized in groups for pre-harvest activities, and there was information regarding support on PHM activities. The government institutions like woreda agricultural offices, Farmers Training Centers (FTCs) and cooperative offices give PHM awareness creation to farmers but it is not in organized and documented manner. The woreda agriculture office has no annual plan and a specific budget for PHM. Only FAO Ethiopia has given training on postharvest management for 15 DAs and 173 farmers to create awareness and understanding on how to minimize loses.

In Soro woreda, there are no sufficient government and non-government institutions working in the area of PHM. Only FAO has recently started training on PHM for 15 DAs and 110 farmers in the woreda.

3.2.2.4. Overview of Wheat Supply Chain

Table 17 presents information pertaining area of production, volume and market of the final product, buyers, and available project support for the wheat subsector at the four woredas. Debre Elias Woreda is among the high producers of wheat in the Amhara region. Wheat production covered 18,820 ha in 2014/15 fiscal year. A total of 12,461 farmers (11,561 males and 900 female) are involved in the wheat production with annual production of 88,736.4 tons.

In Tigray region, Ofla woreda is among the high producers of wheat. A total of 18264 farmers (12785 male and 5479 female) are involved in the wheat production with annual production of 41,102.9 tons from 9,120 ha. Gedeb Hassasa woreda is characterized as one where mechanized wheat farming is practised within the Oromia region and in the country in general. A total of 27,842 farmers (19,868 males and 7,974 female) are producing 103,486.25 tons of wheat annually. Annually 71,428.8 tons of wheat is produced in Soro woreda by 29,762 farmers (23072 males and 6690 female) as a major cereal crop for both consumption and marketing purposes.

Table 17. Wheat supply chains, volume of production, number of farmers, and market outlets Debre Elias, Ofla woreda, Gedeb Hassasa and Soro woredas of Ethiopia

FSC #	Geographical area of production	Final product	Volume of final product (tons/year)	Number & sex of smallholder producers	Market of final product and location,	Project support
1	Debre Elias	Wheat grain	88736.4	F=900 M=11561	Debre Markos, Mekelle, Adigrat, Bahir Dar, Mojo, Dessie	FAO, ATA,
2	Ofla	Wheat grain	41102.9	F=5479 M=12985	Alamata, Mekelle, Maichew, Mehoni	FAO, SARDS, USAID, AGP-AMDE, VOCA, ATA
3	Gedeb Hasasa	Wheat grain	103486.3	F=7974 M=19868	Awassa, Shashemene, Adama, Addis Ababa	FAO
4	Soro	Wheat grain	71428.8	F=6690 M=23072	Hossana, Awassa, Addis Ababa	FAO, Wisdom Fund

Table 18 depicts economic, food and nutritional contribution of wheat from the four study woredas. Wheat from Gedeb Hasasa and Debre Elias immensely contribute to the national food consumption but less to foreign exchange generation. Wheat has a low impact on the environment.

Table 18. Importance of wheat supply chains at national level

FSC #	Economic Importance	Generation of foreign exchange	Contribution to national food consumption	Contribution to national nutrition	Environmental impact	Total
1	3	1	3	2	1	**10**
2	2	1	3	2	1	**9**
3	3	1	3	3	1	**11**
4	2	1	3	2	1	**9**

Table 19 indicates the importance of wheat supply chains for its actors. In all the study areas, a high percentage of wheat is produced by smallholder farmers, generating income and creating employment opportunity for the poor.

Table 19. Importance of wheat supply chains for its actors

FSC #	% of produce by smallholders	Income generation	Involvement of the poor	Employment Provision	TOTAL SCORE Table 17 + Table 18
1	3	3	2	2	**20**
2	3	2	3	2	**19**
3	3	3	3	3	**23**
4	3	2	3	3	**20**

The preliminary screening of food losses in the selected FSC is summarized in Table 20. As can be seen, harvesting, threshing and winnowing, were identified as the quantitative CLPs for wheat in all the studied woredas. However, storage was identified as the quantitative CLP contributing to quantitative losses in Gedeb Hassasa and Soro weredas while field drying is CLP in Soro woreda. On the other hand, in respect of qualitative losses, harvesting was the CLPs for Gebre Hassasa woreda while threshing, winnowing, and storage was identified as CLPs in all the woredas.

Table 20. Preliminary screening of food losses in the selected FSC

Step in the FSC	Expected Loss Points								Comments/Remarks
	Quantitative CLP or LLP				Qualitative CLP or LLP				
	DE	OF	GH	S	DE	OF	GH	S	
Harvesting	**CLP**	**CLP**	**CLP**	**CLP**	LCP	LCP	**CLP**	LCP	High breakage of grain during combine harvesting in GH causing qualitative loss of grain
Field drying	LLP	LLP	LLP	**CLP**	LCP	LCP	LCP	LCP	often drying is completed before harvesting
Transportation to Threshing site	LLP	**CLP**	LLP	LLP	LCP	LCP	LCP	LCP	Often threshing is done at harvest and there is no transportation loss
Threshing/Winnowing	**CLP**	**CLP**	**CLP**	**CLP**	**CLP**	**CLP**	**CLP**	**CLP**	At this is a stage significant qualitative loss is introduced due to urine, faces and soil contamination
Transportation	LLP	LLP	LLP	LLP	LCP	LCP	LCP	LCP	
Storage	LLP	LLP	**CLP**	**CLP**	**CLP**	**CLP**	**CLP**	**CLP**	Both quantitative and qualitative losses occur due to storage pests and poor storage environment
Marketing	LLP	LLP	LLP	LLP	LCP	LCP	LCP	LCP	Less loss due better handling
Processing	LLP	LLP	LLP	LLP	LCP	LCP	LCP	LCP	Losses could be minimal if processing is done on small scale

DE: Debre Elias, OF: Ofla, GH: Gedeb Hassasa, S: Soro

3.2.3. Major supply chain of wheat - Situation analysis

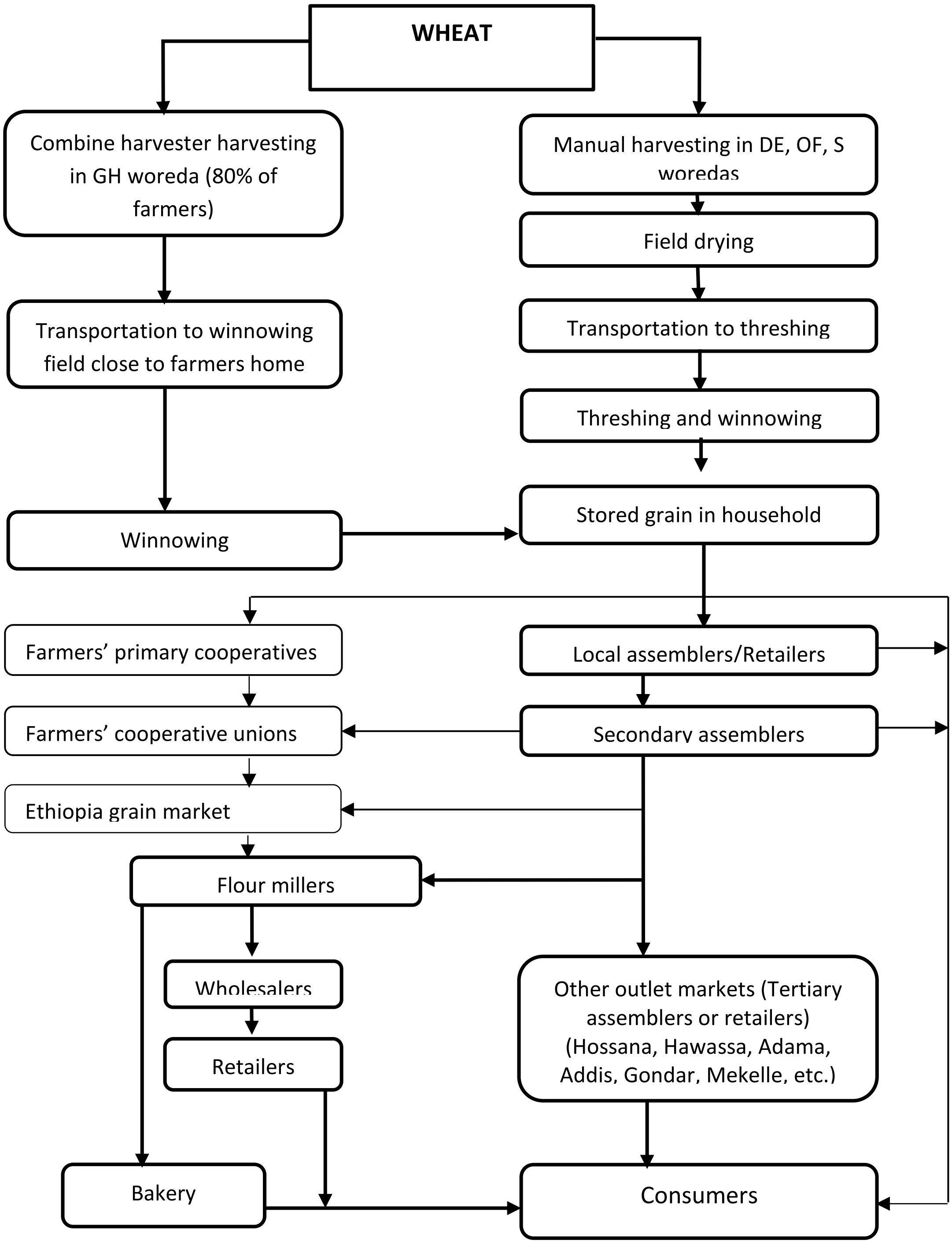
3.2.3.1. Description of the major supply chain

Different actors are involved in the FSC of wheat from different woredas from the stage of harvesting to the final consumers who use the crop as raw grain, flour or baked products such as bread (Figure 11 and Table 21). In all four woredas, the major portion of harvested and stored wheat goes to different destinations through local assemblers. Figure 11 shows the supply chain for wheat in the study woredas whereby lines indicated in bold are the major supply chains. Local assemblers collect wheat from villages and supply it to local level wholesalers. Wholesalers have licensed traders who assemble grains obtained from village level assemblers. Generally, they have small to medium warehouses with a capacity of 0.1 to 5 tons and they supply wheat to a variety of market outlets with careful consideration of the existing market price and their profit margin. They sell wheat to farmers' cooperative unions, flour millers, Ethiopian Grain Trade Enterprise or to other wholesalers as well as retailers in other big nearby towns or at the central market. Eventually, consumers buy either raw grains or flour for preparation of wheat-based products such as backed products, which are sold mainly in the main towns where better marketing opportunity is available.

Table 21. Steps and Products in Wheat Supply Chain

Process	Duration	Product out	Weight from 100 %	Conversion Factor
DE, OF, GH, S woredas*				
Stored grain	2 weeks- 6 months	Whole grain	100	1
Local assemblers	1-2 weeks	Whole grain	100	1
Wholesalers near to villages	2 - 4 weeks	Whole grain	100	1
Primary farmers cooperatives	2 – 4 weeks	Whole grain	100	
Tertiary assemblers	2 -8 weeks	Whole grain	100	1
Farmers' cooperative unions	2 -6 weeks	Whole beans	100	1
Ethiopian Grain Market	3-6 months	Whole beans	100	1
Flour production	Few days - few week	Flour	80	1.25
Baking	1-2 days	Bread	78	1.3

**DE: Debre Elias, OF: Ofla, GH: Gedeb Hassasa, S: Soro*



Note: *Part of the supply chain indicated in bold lines is the major supply chain for wheat from harvesting to consumption.*

Figure 11. The major supply chain of Wheat in the selected woredas

3.2.3.2. Description of the existing marketing systems

This section discusses markets and mode of transport, market chain, price and form of product, market information and major market problems of the wheat subsector in the study woredas.

Debre Elias Woreda

Market places and mode of transport

In Debre Elias, most of the farmers sell their products at Kebele and town markets to wholesalers (90%) with only 10% sold to retailers. Farmers prefer traders to cooperatives when selling their wheat because they obtain their payment immediately while cooperatives have a lower capacity to collect wheat on time and take on credit. In addition, cooperatives have limited access to market information. Wheat from this woredas is transported to different zones and woredas such as Bahir Dar, Debre Markos, Gondar, Dessie, and Woldiya in Amhara region; Adegrat in Tigray region, Mojo in Oromia region and to the capital, Addis Ababa.

Market price and form of product

About 10% of the produce goes to consumption in different forms like *injera, tella, kollo,* bread and *nifro*. In the survey year (August 2015) the average price of wheat was 722 ETB (≈ 35.2USD) per 100kg, and the price per 100 kg ranged from ETB 500 during the bad months (January and February 2015) and to ETB 900 during good months (August and September 2015).

Market information

Access to market information is not well institutionalized in the woredas. Although the woreda grain trade enterprise collects price of cereals every week, the dissemination of price information is so weak that they do not get the right information at the right time and farmers often rely on price information from cooperatives and wheat traders. However, information from the wheat traders may not be reliable.

Major market problems

Most wheat farmers sell their produce immediately after harvest to fulfil household obligations and to settle input debts. There is a glut of wheat in the market during January and February of each year as a result of which the price of wheat falls down by half compared to the peak prices, reaching as low as 400-500 ETB per 100 kg (≈18.4 to 23.0USD/100kg). Therefore, the introduction of cost-effective, efficient storage facility and value chain development are very important mechanisms to enhance farmers' bargaining and price setting power.

Ofla woreda

Market places and mode of transport

Most of the wheat producing farmers in Ofla sell their product at Korem town. Often to traders (30%) and local consumers (70%). However, some of the farmers are organized into cooperatives and are directly supplying their wheat to agro-possessing firms located in Mekelle. The contractual agreement made between Mekelle agro-processing and farmers has brought a good opportunity and the woreda agriculture office is supporting farmers to produce good quality wheat required by the industry. This is a win-win partnership and initiative which could be scaled up to other woredas in Tigray and Ethiopia as a whole.

Market price and form of product

In the survey year the average price ranged between 400 and 900 ETB per 100kg (≈18.40 to 41.40 USD/100kg); however, it is highly dependent on the demand from processing firms. Most farmers sell their produce immediately after harvest to fulfil household obligations like wedding and to settle input debts.

Market information

Access to market information is very limited in the area. Farmers obtain market information from the office of agriculture and cooperatives as well as other farmers but the information is not adequately provided.

Major market problems

The major marketing problems were fluctuation of processors' demand and lower quality of wheat produced by some farmers. Although there is a contractual agreement between farmers' cooperatives and processing firms in Mekelle, it was mentioned that sometimes farmers fail to supply good quality wheat to the processing firms but the woreda agricultural office is giving technical support to curb this problem. Therefore, proper training on how to produce and deliver quality wheat to processing industries should be tailored and offered to farmers and cooperatives.

Gedeb Hasasa Woreda

Market places and mode of transport

Gedeb Hasasa is one of the surplus wheat producing woredas in Ethiopia supplying the majority of its produce (81,340.2 tons/yr) to different markets. The common mode of transporting grain to the market is using trucks and donkey or horse carts. As there is good access to transport facilities and better road quality, getting vehicles is easy and at a reasonable price. The wheat market channels in the woreda include 'producers to consumers', 'producers to cooperatives', 'producers to retailers', 'producers to wholesalers (through local assemblers)', producers to the flour making industry and producers to Ethiopian Grain Trade Enterprise as shown in Figure 11.

Market price and form of product

Price of the wheat varies with seasons of the year. The average price of wheat in 2014/15 season was 874.17 ETB (≈42.64USD) per 100kg. The maximum price of wheat in the woreda was 1020 ETB (≈49.75USD) in July; while the minimum price was 700 ETB (≈34.14USD) in October. Wheat is marketed either as whole grains or wheat flour. There are four wheat flour mills in the woreda and each has an average production capacity of 35-40 tons/day.

Market information

Access to market information in the woreda is relatively good. The Key Informants and the farmers in the focus group discussion mentioned that radio, ECX display board, cell phone communication, Oromia Marketing Agency and extension workers are the main sources of market information. The radio stations providing market information include National Broadcasting Service, Oromia radio and Fana BC (FM 98.1) etc.

Major market problems

The following were market problems identified in the woreda; price fluctuation, unfair price provided by the traders to the farmers, the high cost of transportation and lack of sufficient market information by farmers. Of all these, farmers In Gedeb Hasasa stressed price fluctuation as their major market problem. Moreover, farmers raised the high cost of transportation to nearby markets as another hurdle preventing them from getting their fair share. However, one could see that such claims are so complicated and difficult to unravel as the woreda has good access to transport and market information. The introduction of affordable sound storage systems and proper value chain development could rationale.

Soro woreda

Market places and mode of transport

Farmers sell their wheat at local markets found in the woreda. Women are mostly involved in taking the grain to the local market on their back unless they have a donkey. In most cases, donkeys are the major means of transporting wheat to the market. The transport facilities such as vehicles are not in good condition and roads are of poor quality, and hence only a few farmers use vehicles to take their product to the market. All available modes of transport (human labour, donkey back and vehicle) are used between the months of December and January, the time of the year when most of the products in the woreda are taken to market.

The different market channels of the product are 'producers to consumers', 'producers to cooperatives', 'producers to retailers', ' producers to wholesalers'. The market shares of each chain actor are 12% direct consumers, 60% retailers, 20% wholesalers, and 8% cooperatives.

Market price and form of product

Price of the product varies across seasons of the year. The annual average price of a 100kg of wheat in 2014/15, was 840 ETB (≈40.97USD). The maximum price for the production year was 1050 ETB (≈51.22USD) which happened in July; while the minimum price was 750 ETB (≈36.58 USD). The form of product marketed in the woreda is only whole grain wheat and there is no processed product at a small, medium and large-scale processing units.

Market information

Sources of market information include radio (National Broadcasting Corporation and local FMs), cell phone calls (though it is not frequently used as mentioned by farmers) and the woreda and Kebele extension workers.

Major market problems

Although farmers did not perceive major problems in marketing of their products, the key informants identified several problems including seasonal price fluctuation, unfair price provided by the traders to the farmers, lack of bargaining capacity and price negotiation skill by farmers. Others are lack of understanding (by most farmers) regarding the benefits of joining cooperatives, poor mobile network in the woreda, and control price by traders.

3.2.3.3. Gender Roles in PHM

In addition to their reproductive role, women are the major players in almost more than half of the postharvest activities and they are involved in all stages of postharvest operations. Women are responsible for half of the world's food production, yet their key role as food producers and providers and their critical contribution to household food security is only now becoming recognized (Hassan, 2010). The roles of men and women in the PHM of wheat along the SC are summarized in Table 22 below.

Women farmers in Debre Elias woreda are actively involved in only 25% of the postharvest activities of wheat while men are the decision makers when it comes to the control of income and who should sell the crop. The major roles for women are harvesting, threshing/winnowing and construction of a storage structure known as of *Gotera*. Men take the leading role in 58% of the postharvest undertakings with 17% of the duties carried out jointly by men and women.

Women farmers in Ofla woreda play a key role in the construction of storage facilities, processing and preparation of food for household use. Conversely, men are responsible for making decisions on how and when to sell, transport, treat pests and spend the income. Both men and women equally participate in most of the postharvest activities. As men are exclusively responsible for chemical application for pest control, women make the decision over the use of wheat for consumption.

The wheat PHM division of labour in Gedeb Hassasa woreda of West Arsi zone is equitable. The decision to participate in any activity is made transparently based on discussion and consensus. However, household level processing for consumption is the duty of women.

Gender division of labour of wheat PHM in Soro woreda of Hadiya zone is relatively equitable and is based on the type of activity. The role of women in wheat harvesting is minimum because harvesting demands more energy whereas, on the other hand, transportation requires less energy and is regarded as a women's work. Conversely, the role of men in transportation is low as it is presumed to be a women's responsibility. The decision on how much to sell and consume, who should do what is reached jointly through open and transparent discussion among the family members. On average men do participate in 69% of the postharvest activities while women are involved in 58% of the postharvest activities along the wheat supply chain.

Table 22. Detailed description of the FSC – social structures (gender roles in PHM of wheat)

FSC STEPS	**Women**				**Men**				**Gender / social patterns** **Additional observations and remarks**
	DE	**O**	**GH**	**S**	**DE**	**O**	**GH**	**S**	
Primary production	2	2	2	2	3	3	3	3	Men are in charge of land preparation, fertilizers and pesticides application while women help in collecting weeds and trashes from the land, prepare food and drink for the working people
Harvest	2	2	2	1	3	3	3	3	Women dominate weeding and harvesting. Children also participate.
Post-harvest handling	2	2	2	3	1	3	3	3	Both women and men are involved
Storage	3	3	3	3	2	3	3	3	Both women and men are involved
Transportation	2	1	1	3	3	3	3	3	Men dominated stage because of the limited participation of women in the manual work of loading/offloading
Market sales	1	2	3	3	3	3	3	3	Traditionally dominated by women at local markets
Agroprocessing	3	3	3	3	1	1	1	0	Men dominated since the plant for processing is outside the community & women have mobility restrictions.
Storage	1	1	1	1	3	3	3	3	Dominated by men since it is done through producers' organizations where women have a limited participation.
Transportation	1	1	1	1	3	3	3	3	Men dominated this stage because of social exclusion of women from long distance travel without the company of their close male relatives. Moreover, there are no female long-distance drivers in Ethiopia.
Wholesale	1	2	2	2	3	3	3	3	Dominated by men who deal with buyers at this level
Retail	3	3	3	3	1	1	1	1	Traditionally dominated by women in local markets but they do not necessarily control the price.
Total score	19	20	21	23	23	26	26	25	
% participation	53	56	58	64	64	72	72	69	

DE-Debre Elias; O-Ofla; GH-Gedeb Hasasa; S-Soro,
Gender roles in FSC are rated from 1-3 as 0 = no role, 1= low, 2= medium and 3= high
NB:- Figures don't add up to hundred as there are postharvest activities done by both males and females

3.2.4. PHL of wheat - Study findings

3.2.4.1. Wheat loss risk factors

Food loss is defined as "the decrease in quantity or quality of food". Food waste is part of food loss and refers to discarding or alternative (non-food) use of food that is safe and nutritious for human consumption along the entire food supply chain, from primary production to end household consumer level. Food waste is recognized as a distinct part of food loss because the drivers that generate it and the solutions to it are different from those of food losses (FAO, 2015). Relevant risk factors are indicated in Table 23.

Table 23. Wheat loss risk factors in Debre Elias, Ofla, Gedeb Hassasa and Soro woredas in Ethiopia

Variable	Unit	Relation to food losses- contributing to low losses	Value of variable (observed in the case study)			
			DE	O	GH	S
Crop variety	Y/N	Resistant variety to shattering, insect, diseases	N	N	N	N
Good Agricultural Practices	Y/N	Yes	N	N	N	N
Rainfall during Production	mm	Optimum range	optimum	optimum	optimum	optimum
Production supply/demand ratio	Ratio	> 1	>1	>1	>1	>1
Rain during Postharvest phase	mm	Low rainfall	Y	Y	Y	Y
Postharvest technology	L/M/H	High	H	L	H	L
POs / Coops	Y/N	Yes	Y	Y	Y	Y
Processing technology	L/M/H	High	Y	N	Y	N
Good Manufacturing Practices	Y/N	Yes	N	N	N	N
Packaging materials & facilities	L/M/H	High	M	M	M	M
Cold chains	Y/N	Yes	N	N	N	N
Transport duration	Hour	Low (<1hr)	2½	2	1½	2
Market information	L/M/H	High	H	H	H	H
Price incentive for quality	Y/N	Yes	M	H	M	M
Knowledge of FSC actors	L/M/H	High	H	H	H	H
Consumer access to food product	L/M/H	High	H	M	H	M

Legend: Y/N = Yes / No; L/M/H = Low / Medium / High.

3.2.4.2. Observed PHLs and Critical Loss Points (CLPs)

Debre Elias Woreda

The losses at each point based on the findings of the study are presented in Table 24. Experts and farmers have estimated the total post-harvest loss in wheat between 12.9% and 17.5% respectively. The total average loss of wheat in the woreda is 15.2%. The major critical loss points are harvesting (3.6%), threshing (3.8%), winnowing and storage (5.4%).

Harvesting

One of the key activities in wheat production is harvesting. To decide the right time of harvesting, the degree of the wheat drying at the field level is very crucial. If harvesting is done too early the moisture contents of the grain will be higher which reduces the grain quality. On the other hand, if harvesting is done too late there will be a high loss of grain due to shattering. Farmers harvest their fields when wheat is dry enough and has reached the optimum moisture content. In other areas, wheat is temporarily stored in the field for some time and then threshed afterwards. However, in Debre Elias, farmers ensure that the crop is dried in the field before harvesting, and farmers thresh it immediately on the *"Awdima"*. During this time, the wheat spike or panicle will be prone to mechanical damage. It was observed that when there are labour and time shortages during harvesting, the crop is likely to be over dried in the field.

Farmers in the study area indicated that recently (since the last 5 years) harvesting of wheat is being accomplished using a combine harvester. They also mentioned that a service charge of 90 ETB is paid for harvesting and threshing a 100 kg of wheat. From the discussion with farmers, it was possible to learn that losses are relatively lower when a combine harvester is used. However, if the grain is not well dried, the grain might be rolled flat. Owing to this, loss during harvesting is estimated to be as much as 4.6% of the total harvest.

Field drying/stacking

According to the results obtained through FGD and KII with farmers and agricultural experts from Debre Elias Woreda post-harvest losses of wheat due to drying takes a 1.92 % losses. Farmers mentioned that harvesting is mostly delayed due to a shortage of harvesting machinery and labour resulting in very high post-harvest loss of wheat at drying. Whenever harvesting machines are not used, the harvested wheat is stack in the field and left to dry until fit for threshing (Figure 12).

Figure 12. Field stacking of Wheat for drying

Threshing and winnowing

Most farmers hire combine harvesters with a service charge of 90 ETB per 100 kg which has relieved farmers and oxen labour but, its availability is not reliable in time and space. However, those who cannot afford to pay for a thresher or have smaller fields use human labour and oxen for threshing. Farmers thresh using oxen and trample the grain for hours. This process often results in lower quality grain mixed with pebbles and dirt. Moreover, women then spend days winnowing the pile to separate the grain from the straw resulting in further post-harvest losses.

The method of threshing/winnowing and size of "*Awdima*" used for winnowing has an effect on qualitative and quantitative loss of wheat. Traditional winnowing by exposing the threshed crop to wind leads to higher losses as lighter grains are blown by the wind. Crop loss is higher when the "*Awdima*" is narrow. In addition to this, the grain may also mix with soil during threshing using the "*Awdima"*. When farmers use cattle for threshing, the grain may not be completely separated from the spike and could be thrown away with the chaff.

Transportation

It was found that in Debre Elias Woreda, like the other parts of the country, transportation of wheat from the field to the storage exclusively depends on the use of pack animals. For those who can afford to rent a combine harvester, the harvester will transfer the grain into a truck and the truck will transport the grain to the farmers' door. It was therefore concluded from the study that the loss due to transportation is very low at an estimated 1.95%.

Storage
Farmers in the study area use different types of locally made storage structures which are placed either inside or outside the house. These include *Gotera, Gota, Debignit*, jute sacks, gourds and underground pits. In Debre Elias Woreda wheat grain is mostly stored using *Gota* and jute sacks. There are many factors that result in the postharvest loss of grain during storage. However, major factors are storage Weevil, rodents, and diseases (mould). The loss at this stage, which is estimated at 5.4%, is higher compared to other postharvest activities. A study conducted by Abraham and Senait (2013) in other parts of Gojam like Enebsie Sar Midir and Enarji Enawuga Woredas found that farmers are using several types of storage structures of which farmers find Gotera better because of its capacity to hold more grain and reduce weevil infestation. Typical traditional storage structures used in South Achefer woreda are indicated in Figure 13.

A **B**

Figure 13. Traditional storage structures (A) Gota and (B) Silicha used for grain storage

Ofla Woreda
As indicated in Table 25, the average post-harvest loss of wheat observed along the value chain in Ofla woreda was estimated at 14.2%. The major critical loss points identified were transportation to the threshing field, (3%) at threshing and winnowing (4.1%) and storage (4.5 %) points.

Harvesting
Wheat is harvested manually, using a hand sickle. However, it was reported during the study that a combiner harvesting machine which performs harvesting and threshing operations has been recently introduced by ATA in the woreda.

Harvesting is done during the month of November however; the operation can be extended to December depending on the weather condition and especially (rainfall). The harvest maturity index used to decide the harvesting time is the moisture content of the grain. Over the years, farmers have been using indications such as bending of the neck of the spike of grain, which bends down when the grain is ready for harvest, to decide the harvest time. Unexpected rainfall during harvesting season creates chaos during threshing. During production, frost in the month of October also causes damage.

Hired or family labour is used during harvesting depending on the financial capacity of the farming household and size of the farm. In Korem, wheat is harvested when well dried and is taken directly to the *"Awdima"* which avoids keeping wheat in piles after harvesting for the purpose of drying.

Harvesting technique can also affect how much grain is lost. Some farmers cut short or others cut in the middle of the stalk (An example was given using a case whereby during the 2015 season, someone collected about 200 kg of wheat from half a hectare which was left un-harvested).

It was explained that shattering depends on the cultivar; with the new varieties being more susceptible to shattering. In addition, the right timing of harvest is critical for avoiding shattering. The only time there will be higher loss during harvesting is when there is unexpected heavy rain especially hailstorm, which leads to shattering of the grains. Moreover, accumulation of moisture in the grain structure will result in germination of seeds and assist the germination of spores that eventually leads to rotting.

Harvesting wheat at the right moisture content eliminates a need for field drying which in turn reduces the postharvest losses. Farmers harvest their wheat when the grain reaches its full physiological maturity, which in turn enables them to thresh their wheat immediately.

Various maturity indicators are used to decide harvest maturity. The first and most common one is observing the colour change of the head/kernel (kernel change from green to yellow), bending of the straw near - the kernel, testing the moisture/hardness level of the grain by pressing with fingers and/or teeth, etc. If harvesting is done at full drying stage, threshing is normally carried out immediately. In some cases, threshing will begin within two to three days after harvesting.

Field Drying

According to the explanation provided by the local agriculture experts from Korem Woreda, farmers in the study area do not pile up wheat after harvesting, which entails that wheat in the Woreda does not undergo field drying period after harvesting. This is mostly so since harvesting is normally done while the crop is almost at full physiological maturity.

Table 24.Summary result matrix of wheat loss- Debre Elias Woreda

FSC stage/ process	Type of loss (QN/QL)	% lost in this process (QN)	% product that incurred quality loss in this process (QL)	% product that goes through this stage	% loss in the FSC (QN+QL)	Cause of loss/Reason for low loss	Reduced market value (%)	CLP / LLP	Destination of food loss (discard, consumption, sale)	Stakeholders affected	Impact of PHL at the FSC	Loss perception of FSC actors	Suggested solutions
Harvesting	QN	2.8		100	2.8	mechanical damage; availability of combine harvester is not reliable		CLP	Consumption	Farmers	Income	Less concerned	- Good harvesting practice - Good handling practice - Good transportation - Awareness creation about importance of the crop and need to advise farmers not to involve children on threshing and winnowing of the crop - Proper storage structures and use of insecticides to control insect pests
	QL		0.8		0.8		0.8						
Field Stacking	QN	1.92		96.4	1.92			LLP	Consumption	Farmers	Income	Less concern	
	QL		0		0		0						
Transportation to threshing site	QN	0.5		94.48	0.5	farmers use either pack animals or trucks		LLP	Consumption	Farmers	Income	Less concerned	
	QL		0		0		0						
Threshing /winnowing	QN	2.5		93.98	2.5	Wind effect during winnowing; grain mixed with pebbles and dirt		CLP	Consumption	Farmers	Income	Concerned	
	QL		1.3		1.3		1.3						
Storage	QN	4.2		90.18	4.2	Weevil, rodents, and disease (mould)		LLP	Consumption	Farmers	Income	Concerned	
	QL		1.2		1.2		1.2						
Transportation to market	QN	negligible		84.78	0	-		LLP					
	QL		negligible		0		0						
Marketing	QN	negligible		84.78	0	-		LLP					
	QL		negligible		0		-						
Processing	QN	NA		84.78	-	-		LLP					
	QL		NA		-		-						

Transportation to threshing field

Wheat packed in sacks or other packaging materials is transported to the store using pack animals mainly donkey, and in rare cases on a human head. Wheat in bags is transported from the store to the local market – mostly by pack animals usually, donkeys.

Threshing and winnowing

Most wheat producing farmers use traditional postharvest techniques, such as threshing their harvest by trampling with animals. Under this method, threshing is done by walking an oxen or pair of oxen in circles on the grain on a threshing floor. The method is less efficient in releasing the grain from the chaff and results in a huge grain loss. Moreover, spillage of grains on the floor and consumption of grain by the oxens contribute to massive loss at the threshing.

Storage

As was the case in Korem, harvested wheat goes for threshing, however, without piling for drying. Farmers in this study have already noticed that local varieties of wheat are not susceptible to shattering loss. For short-term storage (1-2 months),) containers such as *Madiga, Aybet* and *Aqumada* are used while farmers use, *Gotera, Bermel, Godo, Gota,* and *Hdmo* (old version of Gotera) for long-term storage (3-6 months or next cropping season). By using such kinds of storage structures, farmers may keep wheat for up to two years, however, there are no evidence regarding the quality of grains.

Gotera is made of Eucalyptus wood, mud, cattle manure, bamboo and straw. White ash is also rubbed on the surface for - beauty. *Shirfa* (*Shenbeqo*) is made up of bamboo and can be kept inside or outside the house. The size of *Shirfa* (> 1000 kg) is greater than *Godo,* which is a ventilated storage of less than 300 kg storage capacity.

To increase air circulation, farmers open storage structures during hot weather. If it rains during threshing, farmers will directly store the harvested grain for a short period and dry it later on. However, if improperly dried grain with high moisture content is stored, weevil will start to develop. Farmers state that if a sack (*Kesha*) is well ventilated, weevil cannot enter, but they have to put in the phostoxin tablets, which are provided by the agriculture office.

Table 25.Summary result matrix of wheat loss- Ofla Woreda

FSC stage/ process	Type of loss QN/QL	% lost in this process (QN)	% product that incurred QL loss in this process	% product that goes through this stage	% loss in the FSC QN+QL	Cause of loss/Reason for low loss	Reduced market value (%)	CLP/ LLP	Destination of food loss (discard, consumption, sale)	Stakeholders affected	Impact of PHL at the FSC	Loss perception of FSC actors	Suggested solutions
Harvesting	QN	1.85		100	1.85	Mechanical damage; availability of combine harvester is not reliable		CLP	Consumption	Income	Farmers	Less concern	- Good harvesting practice - Good handling practice - Good transportation - Awareness creation about importance of the crop and need to advise farmers not to involve children on threshing and winnowing of the crop - Proper storage structures and use of insecticides to control insect pests
	QL		0.8		0.8		0.8						
Field drying/ Stacking	QN	0		97.4	0			LLP	Consumption	Income	Farmers	Less concern	
	QL		0		0		0						
Transportation to threshing site	QN	2.5		97.4	2.5	Farmers use either pack animals or trucks		LLP	Consumption	Income	Farmers	Less concern	
	QL		0.5		0.5		0.5						
Threshing/ winnowing	QN	3		94.4	3	Crop blown by the wind during winnowing; threshing using oxen results in lower quality grain mixed with pebbles and dirt		CLP	Consumption	Income	Farmers	Concern	
	QL		1.05		1.05		1.05						
Storage	QN	2.5		90.3	2.5	Weevil, rodents, and disease (mould)		LLP	Consumption	Income	Farmers	Concern	
	QL		2		2.0		2.0						
Transportation to market	QN	negligible		85.8	-			LLP					
	QL		negligible		-	-	-						
Marketing	QN	negligible		85.8	-	-		LLP					
	QL		negligible		-		-						

Gedeb Hasasa

CLPs of Wheat grain in Gedeb Hasasa woreda were observed to be at the time of harvesting and threshing, winnowing and storage indicated in Table 26. The maximum losses during harvesting and threshing are mainly associated with lack of skilled labour to maintain and operate combine harvesters, poor efficiency of harvesting machines (merely attributed to poor adjustment of the harvester before use) and lodging of the crop on the field before harvesting. In addition to this, loss due to spillage during winnowing including mechanical and wind scattering resulting in a significant loss. However, the use of combine harvesters for harvesting and threshing per se is not the cause for an observed high postharvest loss rather the way and the condition in which we operate them to play significant roles. In addition, storage pests contribute to significant postharvest losses. The above three postharvest practices (harvesting and threshing, winnowing and storage) altogether contribute to an estimated 26.5% of the total loss.

Since there is no regulatory body to control technical efficiency of combine harvesters as well as the unethical behaviour of operators (seeking bribes an incentive), the extent of loss of wheat during mechanized harvesting might even be beyond the indicated value. Therefore, the MoANR together with other stakeholders should develop, and implement strategies pertaining to the standardization and annual check-up for the technical efficiencies of operators and their harvesting and threshing machinery.

Most combiners are privately rented or accessed through government agricultural mechanization services. According to Hassen et al. (2000), topography (accessibility) of a farming area, education level of farmers, and size of the wheat area are factors that significantly determine the decision of hiring or not the harvesting machine. However, the efficiency of the machine in terms of harvesting and threshing is not considered as criteria and there is no controlling body to ensure that combine harvesters involved in harvesting operation have the required technical efficiency. In addition to this, the operations have low technical skill to use the machines and are not aware of postharvest losses of grains due to poor harvesting practices. Therefore, strategies should be developed in this area to control the required efficiency of agricultural machines and to build the capacity of the operators to reach the required technical capacity.

Harvesting and threshing

The peak time for harvesting of wheat in Gedeb Hasasa is October during the *Meher* season while Mohammed et al. (2000) reported November as being the peak time for harvesting of wheat in Hasasa. Before harvesting, the maturity of wheat is conventionally detected by teeth biting and plant physiology. Matured seeds break easily upon biting by teeth and the head or panicle drops down. In some occasions, rain occurs during harvesting which hinders the harvesting process and induces germination of seeds on the spike that in turn affect the quality and yield of the crop.

More than 80% of the farmers hire combine harvester (45 ETB/100 kg) and do both harvesting and threshing at the same time. Less than 20% of farmers use sickles for manual harvesting and oxen trampled threshing. Farmers experience losses during harvesting and threshing of wheat, which is mainly attributed to delayed harvesting and threshing leading to shattering, mould development due to rain, birds and damage by domestic animals, poor handling of grains, type and age of combine harvester used, poor and damaged bags, poor means of transportation that are not leak-proof, and inefficient storage structures and cares. The loss could even be much higher if the area receives an early rain during harvesting time. According to the current estimate in Gedeb Hassasa Woreda on an average 11.5% of wheat is lost during harvesting and threshing.

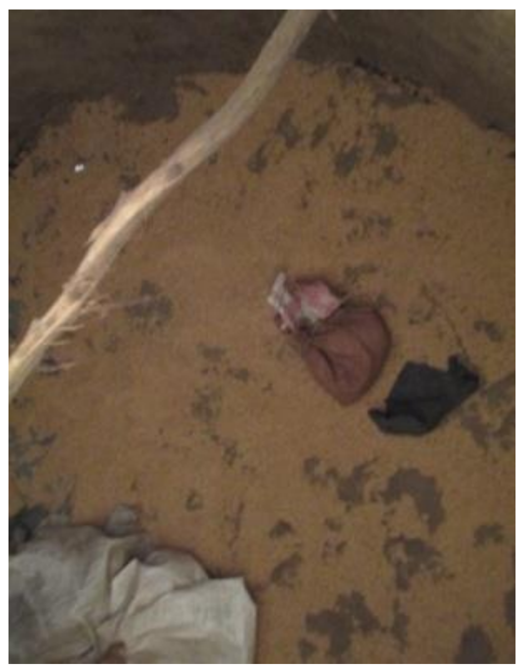
Transportation to winnowing floor and winnowing

As indicated above, more than 80% of the total wheat area is harvested using combine harvesters. After harvesting and threshing, grains are immediately loaded onto trucks or tractor-trailers and transported to pre-prepared winnowing floor for additional cleaning. Winnowing is done to clean grains by removing chaffs and weed seeds. Often the grain is not properly cleaned by combine harvester due to high weed seeds infestation. The other is farmers can use actual yield estimation after they have done winnowing. The major cause of postharvest loss during transportation is spillage of grains through the holes on the floor and gaps between trailer sides. According to farmers and key informants, estimated loss due to such spillage is very minimum; 200 grams per 100kg (0.02%). However, the average loss during manually winnowing is 4.5%, which is attributed mainly due to scattering, wind effect, spillage on winnowing floor and other factors.

Storage

Farmers in Gedeb Hassasa woreda store their grains mainly in polypropylene bags and *"Gotera"*. The latter is made from a woven wooden stick and plastered from inside with cow dung/mud (Figure 14). Major storage problems are associated with storage insect pests, diseases and rodents. Losses due to insects can reach up to 5%, followed by 3% losses due to rodents and 2% because of diseases. These losses can occur because of the extended storage period of grains, especially since farmers store their grain for up to 7 months.

A



B

Figure 14. Traditional storage structures to store wheat grain in Hassasa woreda (A) view from outside, (B) view from inside

Table 26. Summary result matrix of wheat loss- Gedeb Hassasa Woreda

FSC stage/ process	Type of loss QN/QL	% lost in this process (QN)	% product that incurred QL loss in this process	% product that goes through this stage	% loss in the FSC (QN+QL)	Cause of loss/Reason for low loss	Reduced market value (%)	CLP / LLP	Destination of food loss (discard, consumption, sale)	Stakeholders affected	Impact of PHL at the FSC	Loss perception of FSC actors	Suggested solutions
Harvesting	QN	9.2		100	9.2	Mechanical damage; availability of combine harvester is not reliable		CLP	Consumption	Farmers	Income	Less concern	-Good harvesting practice -Good handling practice -Good transportation -Awareness creation about the importance of the crop and need to advise farmers not to involve children on threshing and winnowing of the crop -Proper storage structures & use of insecticides to control insect pests
	QL		2.3		2.3		2.3						
Field drying/ Stacking	QN	0		88.5	0			LLP	Consumption	Farmers	Income	Less concern	
	QL		0		0		0						
transporting from field to threshing area	QN	0.5		88.5	0.05	Farmers use either pack animals/ trucks		LLP	Consumption	Farmers	Income	Less concern	
	QL		0		0		0						
Threshing/ winnowing	QN	3		88	3	Crop taken by wind during winnowing; threshing results in lower quality		CLP	Consumption	Farmers	Income	Concern	
	QL		1.5		1.5		1.5						
Storage	QN	8.5		83.5	8.5	Weevil, rodents & disease		LLP	Consumption	Farmers	Income	Concern	
	QL		1.5		1.5		1.5						
Transport to market	QN	negligible		73.5	negligible			LLP					
	QL		negligible		negligible		-						
Marketing	QN	negligible		73.5	negligible			LLP					
	QL		negligible		negligible		-						

Soro woreda

Critical Loss Points (CLPs) associated with quantitative grain loses are indicated in Table 27. CLPs in Soro woreda for wheat crop during postharvest handling are; storage, harvesting, threshing and winnowing and field drying. Losses at these stages account for 21.0% of the potential harvest. Table 24d also shows the Low Loss Points (LLPs) along the value chain. Factors contributing to LLPs include good packaging during transportation and short duration of grain stay at that stage.

The study revealed that the suitability of topography and small fragmentation of wheat plots have prevented the introduction of modern mechanical harvesting machinery in the woreda. In addition, no efforts have been made to improve traditional storage structures to minimize losses associated with storage insect pests, diseases and poor storage practices. Relevant information pertaining to the extent of PHL for wheat under the mentioned activities are indicated in Table 24d.

Harvesting

Wheat is harvested in November in the *Meher* season only since it is not cultivated in *Belg* season in Soro woreda. Farmers have rich experiences accumulated over years on how to determine the maturity of wheat for harvesting. Wheat is mature and ready for harvesting when the colour of the foliage turns yellow, the seed easily breaks under teeth, and the head of the plant drops down.

Wheat harvesting in Soro woreda is entirely done manually using hand-held sickles and there is no mechanical harvesting. Generally, the whole family is involved in the harvesting of wheat, however, the practice demands more energy, especially tying up bunches of the straws containing grains. Therefore only men are involved in the harvesting of wheat while women and children collect bunches to a common place. In well to do families, hired labourers are involved in the harvesting of wheat.

Like the other study areas, PHL during harvesting is common in Soro Woreda though the amount of loss at harvest depends on several factors like unexpected rain, delay in harvest, variety difference, poor harvesting practice and use of poor quality sickles. In addition, the occurrence of rain during harvesting leads to delayed harvesting. Digalu, one variety of wheat grain, due to its early germination and shattering is more vulnerable to rain than other varieties. Because of these reasons, the estimated loss during harvesting can be as much as 3.7%.

Field drying and transportation to the threshing floor

After harvesting, farmers practice field drying for 1 – 7 days before threshing can commence. Rain, rats, termites, cattle, insect pests, etc. can also cause losses at this stage. The estimated loss because of this practice is 2.50%. After drying, grains with their stalks are transported, mainly on women's back, to the threshing floor. The PHLs occurring during transportation is 1.7%.

Threshing and winnowing

Threshing of harvested wheat in Soro woreda is done between last weeks of November and first two weeks of December. The practice is done on the pre-prepared threshing field, which is commonly levelled and plastered with cow dung. Once farmers are sure of the suitability of the weather condition, trampling of the grains, will be started in the morning and may last for hours or days depending upon volume and easiness of threshing of the crop. This process often results in a lower quality grain mixed with pebbles, cattle dung and dirt. In quantitative terms, threshing cattle may eat grains and grains might be left un-threshed within the straw. Moreover, postharvest loss of grain due to spillage or scattering is common. Women and men then spend few days on winnowing of the grain to separate the grain from the chaff resulting in further post-harvest losses due to mechanical and wind scattering of grains. The estimated cumulative loss due to threshing and winnowing is 4.5%. Farmers in this woreda are not using combine harvesters and other types of small-scale mechanical threshers to substitute their conventional practices. Perhaps this is attributed to the extremely fragmented land holding and raged landscape of the woreda.

Transportation to storage place

Threshed and cleaned grain is normally packed in polypropylene bags and transported to storage places using either human labour or donkey. Since threshing fields are located near farmer's homes, this is a brief period of postharvest practice. According to the information gathered from farmers and key informants, quantitative loses due to poor transportation materials and improper handling is less than 1.0%. The transportation loss from the threshing field to storage place is also not significant (<0.5%) due to good care - as well as short distances involved.

Storage

Storage of grains is one of the major postharvest activities of wheat in the Woreda. Grains are stored in "*Secha* or *Kefo*" (a structure made from bamboo and plastered from inside with mud and polished by a cow dung having a capacity of 1000-2000 kgs), polypropylene bags and big clay pots are also used to store small volume of wheat. Farmers commonly clean storage structures from previous years before they store the new grains. Depending -on the production capacity of a farmer, intended use of the grain, market price and other factors, grains can be stored for up to 7 months. Due to an extended period of storage together with other conventional storage practices, total loss of grain during storage can reach 6.3% of the total stored grain. Loses are commonly caused by storage insect pests, diseases, rats, chicken, goats and mishandling of grains.

Table 27. Summary result matrix of wheat loss: Soro Woreda

FSC stage/ process	Type of loss QN/ QL	% lost in this process (QN)	% product that incurred QL loss	% of product that goes through this stage	% loss in the FSC QN+ QL	Cause of loss/ Reason for low loss	Reduced market value (%)	CLP / LLP	Destination of food loss (discard, consumption, sale)	Stakeholders affected	Impact of PHL at the FSC	Loss perception of FSC actors	Suggested solutions
Harvesting	QN	3.2		100	3.2	Mechanical damage; loss due to shattering		CLP	Consumption	Farmers	Income	less concern	- Good harvesting practice - Good transportation - Good handling practice - Awareness creation about importance of the crop and need to advise farmers not to involve children on threshing and winnowing of the crop - Awareness creation about importance of the crop and need to advise farmers not to involve children on threshing and winnowing of the crop - Proper storage structures and use of insecticides to control insect pests
	QL		0.5		0		0.5						
Transport from field to threshing area	QN	1.5		96.3	1.5	Farmers use either pack animals or trucks		LLP	Consumption	Farmers	Income	less concern	
	QL		0		0		0						
Field drying/ Stacking	QN	1.5		94.8	1.5			LLP	Consumption	Farmers	Income	less concern	
	QL		0		0		0						
Threshing/winnowing	QN	3		93.3	3	Wind effect during winnowing; lower quality grain mixed with pebbles		CLP	Consumption	Farmers	Income	concern	
	QL		1.5		1.5		1.5						
Transport from threshing field to home	QN	2		88.8	2			CLP	Consumption	Farmers	Income	concern	
	QL		1.5		1.5		1.5						
Storage	QN	5.1		85.3	5.1	Weevil, rodents, and disease (mold)		LLP	Consumption	Farmers	income	concern	
	QL		1.2		1.2		1.2						
Transportation to market	QN	negligible		78	0			LLP					
	QL		negligible		0								
Marketing	QN	negligible		78	0			LLP					
	QN		negligible		0								

3.2.4.3. Causes of losses and identified loss reduction measures
Information provided in Appendix Figure 1 shows the basic, underlying and immediate causes of losses along the wheat supply chain and with associated losses indicators and type of losses. The basic causes associated with issues - at the macro level are the absence of supporting policies, infrastructures and economic capacity of the nation and the country as a whole. Underlying causes are related to absence of service providers and technologies, trained human power as well as economic limitation of farmers to use available services and technologies to reduce postharvest losses. The cumulative effects of the above causes lead to immediate causes, which can be expressed in terms of physical, chemical, biological and cultural practices, which will be manifested by various indicators.

Losses attributable to the various factors can be minimized by implementing the appropriate loss reduction measures. For instance, farmers who harvest their crop at the proper time and moisture content can minimize loss during harvesting. Furthermore, as witnessed by farmers in the Gedeb Hassasa and Debre Elias, combine harvester, if used properly, minimizes losses by shortening harvesting time, field drying and threshing. Moreover, over the years, farmers have developed traditional methods of preventing storage pests through mixing wheat grain with Teff during storage and fumigation of the storage structures with different smoke sources. Traditionally, leaves of “Chew” (a climber plant) are rolled and put into storage structure in order to minimize weevil infestation. Nowadays, farmers are also using various pesticides (insecticide and rat killers) to control storage pests.

3.2.4.4. Low Loss Points (LLPs) and good practices
Low loss points (LLP) in the supply chain of Wheat for all four woredas under the study are almost the same. In all woredas, losses associated with transportation of non-threshed and threshed not threshed or threshed grain is minimum as compared to other postharvest activities. For instance, loss due to transportation from harvesting field to threshing floor is estimated as 1.95, 2.5 and 1.70% in Debre Elias, Ofla and Soro woredas respectively. Meanwhile, transportation loss from harvesting field to winnowing floor in Gedeb Hassasa is below 1.0%. These minimum losses are mainly due to the utmost care that is taken by farmers as they transport wheat. The same trend was observed when farmers transport their grain from threshing field to storage place as well as from storage to marketing. As a good practice, farmers use processed cattle skin, mosquito net, polypropylene sheets and other materials to wrap up the harvested crop before they move it to the threshing field. Furthermore, such activities are commonly done early in the morning to 10.00 am or late afternoon after 4.00 pm to minimize the possibility of grain losses due to shattering.

3.2.5. Wheat loss reduction strategy - conclusions and recommendations

3.2.5.1. Impact of wheat losses
The estimated amount, value, and calories of postharvest food losses in the study woredas is presented in Table 28. In 2014, the average amount of wheat lost was 13.5K ton, 5.8K ton, 27.4K and 15K tons per year in Debre Elias, Ofla, Gedeb Hasasa and Soro respectively. The value of wheat loss in 2015 was estimated at more than 4.7, 1.8, 11.7 and 6.1 million USD per year for Debre Elias, Ofla, Gedeb Hasasa and Soro woredas respectively (Table 28). This amount of wheat loss translates into 45.7M, 19.8M, 93M and 50.8M kcal per year for Debre Elias, Ofla, Gedeb Hassasa and Soro respectively in 2015. Using the FAO suggested calorie intake cut-off of 1820 kilocalories per person (Schmidt and Dorosh, 2009), the total amount of calorie lost (794M kcal) could have nourished 436,520 Ethiopian adults. This wheat loss estimate is based on calories alone and does not address the more complex nutritional needs of individual people, such as for specific vitamins and minerals.

Table 28. Monetary and calorific losses of wheat in the study woredas due to wheat losses

Woreda	Percent weighted loss (%)	Total production (tons/year)	Weighted loss (tons/year)	Price of grain per ton per woreda	Loss in Monetary Value (USD/yr)	Productivity of crop (tons/ha)	Loss of cultivated land (ha) due to PHL	Caloric value loss (kcal/yr) Billion
D. Elias	11.40	88,736.40	10,133.10	352.00	3,566,861.40	4.70	2,156.00	3.44
Ofla	9.60	41,102.90	3,947.40	317.00	1,251,332.06	4.50	877.20	1.33
G.Hassasa	20.10	103,486.30	20,822.00	426.40	8,878,484.17	3.50	5,949.10	7.06
Soro	15.70	71,428.80	11,234.90	409.70	4,602,935.70	2.40	4,681.20	3.80
Total	**56.8**	**304,754.40**	**46,137.40**	**1,505.10**	**18,299,613.33**		**13,663.50**	**15.63**
Mean	**14.2**	**76188.6**	**11534.35**	**376.28**	**4574903.333**	**3.775**	**3415.88**	**3.9075**

**There are 339 calories in 100 grams of Whole Wheat Flour (Marquart et al., 2008)*

3.2.5.2. Required inputs and cost-benefit analysis of wheat loss reduction measures

Considering various postharvest activities of wheat and associated losses, it is possible to recommend some strategies that can contribute towards loss reduction. For instance, one of the main causes of losses in the different woredas is associated with harvesting and threshing of the crop. However, it will be inappropriate to just recommend a modern harvest combiner for the small-scale farmers. But under a favourable working environment and a supporting policy, other private mechanization providers can offer the service at a reasonable price. It is also difficult to recommend such type of technology for relatively low producing woredas, areas with difficult topography as well as fragmented farm lands. Therefore, in this part, only technologies that are important, relevant and economical to reduce the postharvest loss of wheat during storage should be considered. Storage related losses are considered as being high and therefore storage stage in the supply chain need needs and need attention. Use of simple hermetic storage technologies such as hermetic bags and metal silos can reduce or avoid losses caused by storage pests as well as adverse environment conditions. As indicated in Annex Table 9 and 10, average storage related loss is 6.6%, and hence to reduce this loss by 95% using hermetic bags will result in a benefit of 25 USD/yr, but with the current price of 219 USD for a hermetic silo of 1 ton capacity the cost-benefit is not feasible. However, the introduction of incentives during the manufacture of metal silos as well as organizing and capacitating local artisans that can produce such technologies at a relatively lower price, without compromising the quality and service, may render the use of metal silos economically feasible.

3.2.5.3. Wheat loss reduction plan and strategy

Loss reduction strategies are designed and developed as per observed CLPs indicated in Table 25-27. The CLPs of wheat in Hassasa woreda are mainly associated with combine harvesting, winnowing and storage of grains. Most combine harvesters are privately rented or accessed through government agricultural mechanization services. According to Hassen et al. (2000), topography (accessibility) of a farming area, education level of farmers, and size of the wheat area are factors that significantly determine the use of harvesting machine. However, the efficiency of the machine in terms harvesting and threshing is not considered as criteria and there is no controlling body to insure that combine harvesters involved in harvesting operation have the required level of technical efficiency. In addition, operating personals have low technical skills to use the machines and -are not aware of the postharvest loss of grains. Therefore, a policy should be developed in this area to control the required efficiency of agricultural machines and operators with the required technical skill. Winnowing is another factor that imposes additional loses. This is mainly associated with the use of existing conventional practice that results in loss of harvested and transported grains. It is necessary to conduct research in this area to develop more efficient and prudent technology to minimize losses. It is also important to introduce medium or large-scale harvesting and threshing machines in other woredas in the country. Introducing such type of technologies will significantly reduce the losses associated with harvesting and threshing. Storage related losses can be reduced through improved storage structures and use of different storage pest control measures like use of insecticides and pest and prudent storage structures. However, in general farmers use different traditional approaches and methods to minimize post-harvest loss: These includes,

- Allowing wheat crop to dry to optimal moisture content before harvesting to avoid mould - after harvest
- During storage, farmers try to sort their crops into different quality (high, medium and low) to reduce loss due to mix- up of different quality product
- Adding and mixing ash to avoid stored wheat from attack by storage pests especially for weevil management.
- Use of sealed containers with small opening e.g. Hermetic bags and metal silos) as best storage structure for management of post-harvest loss reduction.

Other traditional methods for pest control include:

- Cleaning grain storage structures before storing their crops.
- Smoking the storages (Gotera and Gota) with red pepper powder,
- Using pungent pepper powder on a stored wheat grain as a repellent to storage insects

3.2.5.4. Follow-up action plan

Losses happen at different postharvest steps, but the extents vary at each stage of postharvest activity. Training and awareness creation in terms of major causes of postharvest losses and associated loss reduction mechanisms are important inputs to minimize losses. In addition to this, the introduction of mechanized equipment in relation to postharvest handling and processing of grains not only avoids limitations of conventional practices to reduce loss but also promotes value addition steps. Availability and affordability of technologies resistant to various pest and adverse environment with prudent and durable structures are important to avoid storage-associated losses. The use of hermetic plastic bags, like ProGrain or Triple bag, is appreciated but the issue of price per bag, availability, and structural or mechanical integrity need fine tuning to adopt the technology widely throughout the country. Supporting policy in the area of postharvest practices is critical in boosting the efficiency of operations of the stakeholders involved in postharvest related activities. Furthermore, there is a need to support and promote the availability of affordable storage facilities to avoid wheat storage losses.

3.3. Postharvest loss assessment of sorghum

3.3.1. Status and importance of sorghum in Ethiopia

Sorghum (*Sorghum bicolour* (L.) Moench) is a tropical cereal grass cultivated in the warmer climatic areas across the world. Ethiopia is the second largest sorghum producer in Africa, after Sudan (Demeke Marcantonio, 2013) and is a sixth global producer with a share of 7% of the total global sorghum production (FAOSTAT, 2015). Sorghum is one of the most important commodity crop grown in different low laying plains of Ethiopia. According to FAO, its production has significantly increased from 1.7 million tons in 2004/05 to nearly 4.0 million in 2013 (130%) (FAO, 2013). Although the production decreased by 2.77% from 2013 to 2014.

Sorghum is one of the major staple crops grown in the poorest and most food-insecure regions of Ethiopia. The crop is typically produced under adverse conditions such as low input use and marginal lands (FAO, 2013). Its drought tolerance and adaptation attributes have made it a favourite crop in drier and marginal areas. All of the sorghum produced in the country is used for domestic consumption and its contribution to food security is significant.

Nearly 4.5 million smallholders located in the eastern and northwest parts of the country cultivate sorghum. The main sorghum producing regions are Oromia, Amhara and Tigray, accounting for nearly 90.4 % of the total production (FAO, 2013). The leading sorghum producing zones are East and West Hararge in Oromiya, North Gondar (Armacho) and North Shoa in Amhara, South Tigray (Alamata) and Derashe in SNNP.

Sorghum producing woredas selected for the present assessment were Alamata from Tigray, Fadis from Oromia, Derashe from SNNP and West Armacho from Amhara regional states. Based on secondary data information from Raya Alamata woreda the annual production is estimated at 864,000 tons from 18,000 ha of land. Average yield per hectare reaches 4.8 tons. The same source indicates that the average production for the last ten years increased by 15%. Predominantly, sorghum produced in Alamata woreda is mainly used for household consumption (60%), while the remaining 40% is sold to retailers for the purpose of income generation. The available secondary data in Alamata woreda also shows that all - farmers, (23,359 households,) in the woreda –produce sorghum. Table 29 describes production status and economic importance of sorghum in Alamata Woreda of Tigray regional state.

Table 29. National and woreda levels data on cultivated land, total production, consumption, marketing of Sorghum

<table>
<tr><th colspan="10">National Sorghum</th></tr>
<tr><th colspan="3">Annual production (tons/yr) (average of 8 years 2003/04-2013/14)</th><th colspan="3">Cultivated area (ha) (average of 8 years 2003/04-2013/14)</th><th colspan="3">Average yield (tons/ha) (average of 8 years 2003/04-2013/14)</th><th>Remark</th></tr>
<tr><td colspan="3">28,916,406.6</td><td colspan="3">1,585,134.3</td><td colspan="3">1.80</td><td>Average values of last 10 years 2003/04 to 2013/14 (CSA Abstracts 2003/04-2013/14)</td></tr>
<tr><th colspan="10">Average annual growth for the last 8 years (%)</th></tr>
<tr><th>2004/05</th><th>2005/06</th><th>2006/07</th><th>2008/09</th><th>2009/10</th><th>20010/11</th><th>2011/12</th><th>2012/13</th><th>2013/14</th><td rowspan="2">Calculated based on CSA abstract from 2004 to 2014</td></tr>
<tr><td>21.1</td><td>6.2</td><td>12.9</td><td>5.2</td><td>5.6</td><td>DNA**</td><td>24.8</td><td>-9.6</td><td>5.9</td></tr>
<tr><th colspan="10">Average cost of production (USD/ton)</th></tr>
<tr><td colspan="9">318.2</td><td>Considering average cost of production of four studied woredas in 2015</td></tr>
<tr><th colspan="9">Percentage for consumption, % PHL and % marketed in household level</th><td rowspan="4">Data calculated from average values of three woredas report of Alamata, Derash, Fedis and West Armacho in 2015 (Sorghum grain)</td></tr>
<tr><th colspan="3">Percent consumed</th><th colspan="2">Average PHL during storage of grain</th><th colspan="4">Percent Marketed= Total -%PHL-% consumed</th></tr>
<tr><td colspan="3">76.3</td><td colspan="2">11.3</td><td colspan="4">12.4</td></tr>
<tr><th colspan="9">Value of Marketed product # 1 sorghum (USD/year)</th></tr>
<tr><td colspan="9">18,967,762.2</td><td>This value is calculated as total production *percent marketed*price of one ton of maize grain (253 USD)</td></tr>
<tr><th colspan="9">Number and sex of Producers</th><td rowspan="3">Total number of producers of the three woredas in the study area.</td></tr>
<tr><th colspan="3">Male</th><th colspan="3">Female</th><th colspan="3">Total</th></tr>
<tr><td colspan="3">66,535</td><td colspan="3">14978</td><td colspan="3">81,513</td></tr>
<tr><th colspan="9">Levels of trading and processing operations</th><td></td></tr>
<tr><th colspan="3"></th><th colspan="2">Small</th><th colspan="2">Medium</th><th colspan="2">Large</th><td></td></tr>
<tr><td colspan="3">Level Whole sale operation</td><td colspan="2">-</td><td colspan="2">*</td><td colspan="2">-</td><td></td></tr>
<tr><td colspan="3">Level of retail operation</td><td colspan="2">-</td><td colspan="2">-</td><td colspan="2">*</td><td></td></tr>
<tr><td colspan="3">Level of processing operations *</td><td colspan="2">NA</td><td colspan="2">-</td><td colspan="2">-</td><td></td></tr>
</table>

**DNA=Data Not Available

West Armacho Woreda of the Amhara region, which is characterized by warm and dry environmental conditions, is suitable for sorghum production. Table 29 describes the details production status and economic importance of sorghum in West Armacho. Sorghum production in the area covers 26.7 % (34,300 ha) of the total agricultural lands from which about 85,750 tons of grain are produced with an equivalent value of 299.2 USD/ton. The average yield per ha is 2.5 tons. The average growth rate over a period of three years was 13% (no data for longer periods). In spite of the crop importance in this woreda, the land allocated to sorghum has been declining because of the competition with high-value crops like sesame. The woreda office of agriculture indicated that if this trend continues in sesame and other crops may totally replace the future production of sorghum. Therefore, sorghum production and marketing may be affected by the low attention rendered by investors and land use competition with high-value crops.

Derashe woreda in Southern Nations, Nationalities, and Peoples' region (SNNP) of Ethiopia produces sorghum and the crop is more than a food grain for the Derashe people. Its area coverage is the largest as compared to other crops like maize and is produced two times per year from the main cropping season and ratoon crop during the off-season. Due to its remote location, a major portion of the sorghum is consumed within the same woreda and yet it has a significant contribution to the economy of the woreda. Table 29 describes detail production status and economic importance of sorghum in Derashe woreda of SNNP.

Fedis woreda is known as one of the sorghum producing woreda in Eastern Hararge zone of Oromiya Regional State. As it is with the case the other woredas, sorghum is the major staple food crop in Fedis. Out of the total volume of production, 90% is consumed at the household level. Therefore, as compared to other cereal crops like maize, sorghum covers a major portion of the cultivated land. Details pertaining to production status and economic importance of the crop in the woreda are indicated in Table 29.

Actors and product flow diagram of sorghum supply chain in the four study woredas is presented in Figure 15. As indicated in the diagram, the main actors in the sorghum supply chain are the producers (the farmers) and the final consumers. In the marketing activities of sorghum, wholesalers, assemblers, retailers and rarely cooperatives are involved. The lion’s share of sorghum produced in each woreda is locally consumed often by the families of the producers (60% in Alamata, 90% in West Armacho and Fedis and 65% in Derashe) and to a lesser extent by rural and urban consumers (40% in Alamata, 10% both in West Armacho and Fedis and 32% in Derashe).

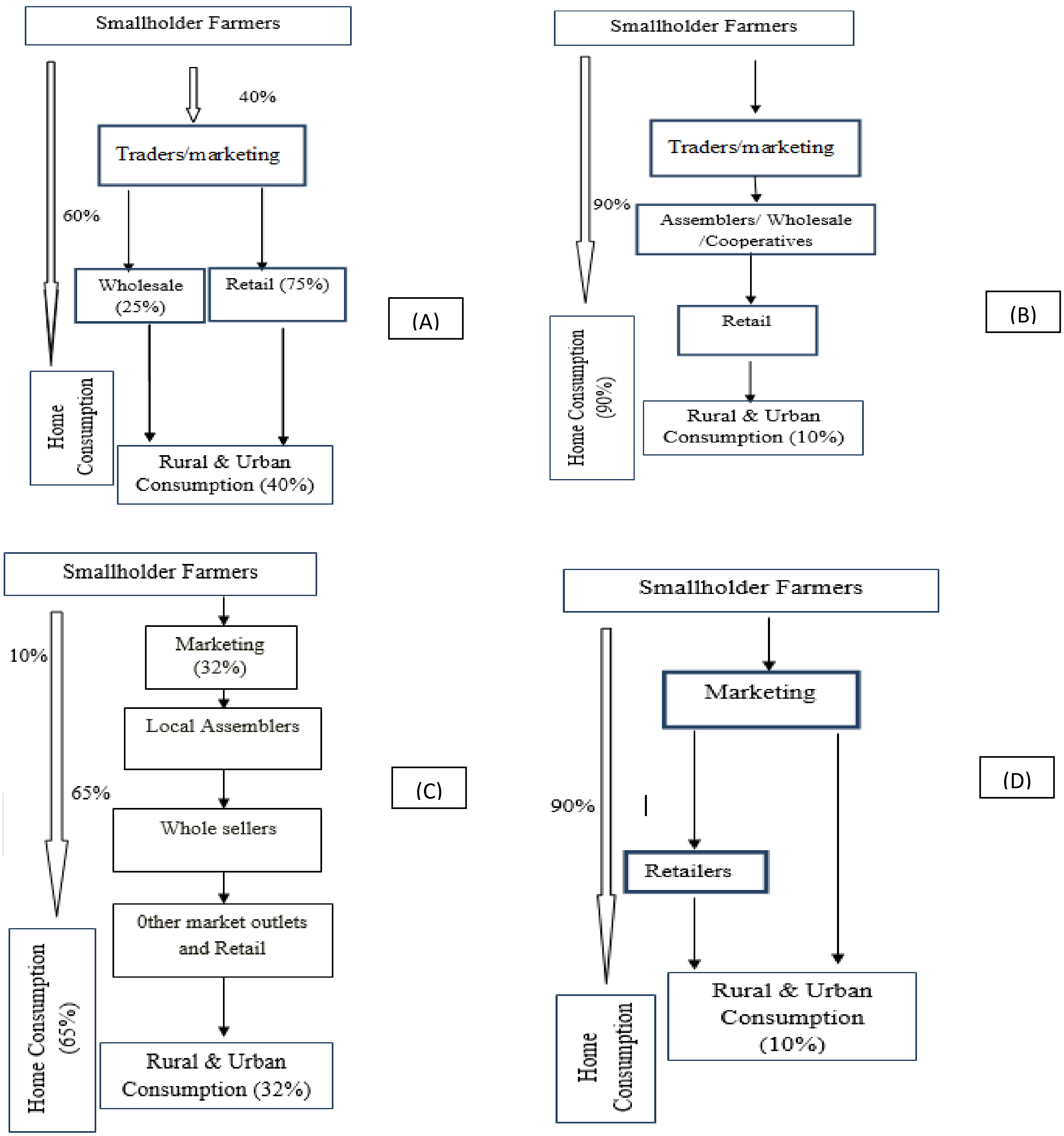


Figure 15. Actors and product flow in the sorghum supply chain in (A) Alamata, (B) West Armachiho, (C) Derashe and (D) Fedis woredas of Ethiopia

3.3.2 Past and on-going interventions in sorghum loss reduction

Reduction of postharvest losses requires an appropriate intervention through well-coordinated efforts of many governmental and non-governmental institutions. Oftentimes interventions are so fragmented and redundant which results in wastage of the scarce resources and no synergies are observed. Interventions in the area of postharvest management could be assessed from education, research, extension and development perspectives. In this context, several institutions have been engaged in postharvest related activities in view of achieving postharvest loss reduction. However, there is hardly any comprehensive database to refer to in order to understand who is working on what and capitalize on best practices achieved through the implementation of the respective intervention projects in the country.

In the area of education, there are currently different universities in Ethiopia offering training at different levels pertaining to postharvest management or related fields. Jimma University launched its BSc Postharvest Program in 2009, which later on evolved to MSc and PhD. In addition, there they are offering tailor-made training to DAs and Artisans pertaining postharvest technologies and general postharvest management issues. Other universities including Hawassa University, Haramaya University, Bahir Dar University, Mekelle University, Wollega University, Ambo University, Addis Ababa Science and Technology, Adam Science and Technology University, Addis Ababa University, and Arsi University are also offering training related to postharvest management. FAO is delivering targeted PHM training to Das who in turn train the local farmers. Similarly, Artisans have been trained by FAO, in collaboration with Melkassa Agricultural Center, on issues pertaining to construction and maintenance of Metal silo storage structures.

Sorghum producers in all studied woredas are practising the traditional postharvest management practices. Postharvest activities including harvesting, field drying, transporting, threshing, winnowing, packaging and storage are done using the existing indigenous knowledge. The existing extension system in Ethiopia puts more emphasis on pre-harvest field activities. Therefore, it is high time that postharvest component is strengthened in the existing extension system of the country. In line with this, there are on-going efforts being made by GoE (MoANR) and non-governmental organizations including SG2000 and FAO to popularize the effective use of hermetic storage structures to store different kinds of grains for both consumption and seed use.

NGOs and international organizations such as SAA, ACIDI-VOCA, and IPMS are extending improved technologies to the end users and service providers. The growing demand for improved technologies necessitates that they are available and accessible to farmers and processors. For example, the SAA-AP project is working closely with the Extension Department of the Ministry of Agriculture and Natural Resources, and Selam Technical and Vocational Center (STVC).

The MoANR's mandate is to continue linking farmers and processors to the technology-resource system; STVC is responsible for the production, sales and servicing of machines demanded. They have an important role in adapting and modifying the agro-processing machines for an introduction to the Ethiopian farmers as required by their environment. STVC is also home to the SAA-AP project in Ethiopia. It provided a metal workshop and an office and granted a special privilege to access and use its other facilities and services to the project team. Working with well-established institutions like STVC in order to speed up the scaling up of postharvest technologies and thereby improve the welfare of the small-scale farmers and processors can facilitate the extension work in Ethiopia. Moreover, capacitating the small-scale enterprises including the local artisans will make postharvest technologies more accessible to end users.

Over the last 10 years, the SAA-IITA Agro-processing Project has disseminated different types of machines for processing different farm produce in Ghana and Benin extending to other African countries such as

Ethiopia. SG2000 is also promoting the use of hermetic metal silo and Purdue Improved Crop Storage (PICS) bag for storage of grains. PICS bag is relatively cheap and can be used repeatedly for at least three seasons. On the other hand, although hermetic Metal silos are relatively costly however can be used for more than 15 years and thus can offset the initial relatively high price. However, the adoption of these storage structures is just picking up. Provided that the government of Ethiopia designs a special schemes or incentives to bring down the cost of the galvanized metal sheet, which accounts for almost 90% of the total cost, it is possible to distribute the technology to more users.

The multi-crop threshers being promoted by the SAA-AP project have a field capacity of 500 to 600 kg per hour and have significantly reduced time and drudgery of using the traditional method. The effort to adapt the thresher to local conditions was done by the SAA-AP project in collaboration with STVC by developing the donkey carts where the thresher can be mounted for transport (Figure 16). This enables the operator to conveniently move the thresher around the farms.

Figure 16. A service provider transporting a thresher using a donkey cart to a village where the service is required

The farmers have evaluated the thresher for maize, wheat, barley, sorghum and millet and the feedback received so far is encouraging. The SAA-AP project team is now addressing recommendations for improvement, while continuously doing with demonstration and awareness creation campaigns in other parts of Ethiopia.

Processing of grain and cereals in Ethiopia using the multi-crop thresher has opened up business activities among teff and maize farmers in Ethiopia. Service-providers are active in offering services to the farmers while making a good profit whereas service-users benefit by saving time and reducing field losses of their crops.

FAO through its office in Ethiopia and in collaboration with the local partner MoANR is implementing a postharvest project sponsored by SDC aimed at reducing food loss through post-harvest management. There is an ongoing effort to support MoANR to prepare postharvest policy and strategies for grains and pulses. Moreover, the Agricultural Mechanization Directorate in the MoANR, has already developed a strategic document to mainstream postharvest mechanization. Research in the area of postharvest management is virtually nil and highly uncoordinated, though there is an on-going effort to prepare postharvest research policy at National Agricultural Research System (NARS) level. Postharvest platform was established on 2 January 2016 under the umbrella of MoANR. Postharvest Management Society of Ethiopia has been launched and legal registration is completed.

3.3.2.1. Policy issues in sorghum PHL reduction

In general, postharvest harvest initiatives in Ethiopia have received little attention. However, it still holds true that sustained political commitment at the highest level is a prerequisite for reduction of postharvest losses. Considering the role of postharvest in ensuring the national food security, it is necessary to place the need for appropriate management top in the political agenda. In addition, it is important to create an enabling environment through adequate investments, better policies, legal frameworks, stakeholder participation and a strong evidence base. Institutional reforms are also needed to promote and sustain progress in postharvest handling, value addition and effective marketing. In this context, Ethiopia has made a good stride in developing a number of policies, strategies and plans that have a direct or indirect relationship to postharvest management.

The Ethiopian Government has already formulated an industrial development strategy with clearly defined objectives, targets, budgets and institutional setups required for implementation. Three key overarching policy documents were developed to guide interventions in the sector over a 13-year period (2013-2025). These are: the Industrial Development Roadmap (IDR), which provides a strategic framework for industrial development for the next ten years; the Industrial Development Strategy Plan (IDSP), which defines strategies, programs and projects for the implementation of IDR; and the Industrial Development Institutional Setup (IDIS), which provides an institutional framework for industrial development. The strategy is guided by Vision 2025, which aims to transform Ethiopia into a middle-income country by 2025. With this objective in mind, the Government developed a number of policy documents, including: the Plan for Accelerated and Sustained Development to End Poverty (PASDEP); the Growth and Transformation Plan I (GTP I) for the period 2010-2015, - followed by GTP II (2015-2020); and, the Agricultural Sector Policy and Investment Framework (PIF) for the period 2010-2020, as well as various other sector-specific plans.

In the PASDEP document, it is mentioned that one of the main reasons for low agricultural production is the severe damage caused by various types of plant pests such as insects, mites, diseases, weeds and vertebrate pests like rodents and birds. Average crop losses due to these pests during the pre-harvest period is estimated at 30% or even higher, depending on pest severity and extent & success of plant protection measures applied. The post-harvest crop loss is also estimated to be 15%. During the period of the implementation of PASDEP, pre-harvest loss is expected to be reduced to 25% and postharvest loss to 10%. The postharvest issue under this plan only briefly indicated under pest control section considering only storage structures and storage pest as a major postharvest problem. In its section 7.1.6b, it says that *"Appropriate training will be given to pest-control personnel and farmers. Methods for postharvest loss management will be developed and disseminated through extension packages to promote improved storage structures and practices"* (FDRE, 2006). Accordingly, development and dissemination of extension packages and promotion of improved storage structures and practices have been proposed as part of the post-harvest loss management strategies.

However, details of implementation strategy pertaining to improved storage structures and practices have not been put in place. In connection with postharvest management, the strategy throws some light on storage of agricultural products for promoting marketing. PASDEP, in its section 2 sub section 2.9.2, has given details on how to promote marketing of agricultural products. Section 2.8 of PASDEP also mentions that the Food Security Program as a special arrangement, which focuses on addressing vulnerability existing in different parts of the country. However, reduction of postharvest losses and scaling up of good postharvest management efforts have not been considered regardless of the multi-pronged contribution that postharvest management has in assuring the dependable availability of sufficient, safe and nutritious food.

Following PASDEP, GTP-I underpins three important strategic areas required to forge agricultural growth in the country namely 1) increasing productivity of smallholder farmers; 2) Improving NRM and promoting irrigation, and 3) increasing participation of smallholder farmers in agricultural marketing and production of high-value crops.

Today, standing unique among African countries, the GoE allocates more than 10 percent of its national budget for agricultural and rural development. Ethiopia was also a leader within Africa, recognizing that progress is sometimes challenged by certain constraints and lack of coordination between policy and implementation resulting in fragmented and disconnected implementation initiatives on the ground. In 2010, the GoE, with the input experts from Asia, established the existing Ethiopian Agricultural Transformation Agency (ATA).

The draft AGP-II (FDRE, 2015) developed by MoANR in Ethiopia consists of five components. I: Public Agricultural Support Services; II: Agricultural Research; III: Smallholder Irrigation Development; IV: Agriculture Marketing and Value Chains; and V: Project Management, Capacity Building, Monitoring, and Evaluation. The plan provides emphasis to agro-processing and value addition, storage of priority commodities for the selected woredas and general postharvest handling. However, it does not clearly outline details of the activities under the postharvest initiatives.

3.3.2.2. Relevant institutions and their roles in PHL reduction of sorghum

A concerted effort is being made at national level to improve total production and productivity of crops and thereby ensuring food security in Ethiopia. Because of this effort, a significant increase in terms of total area cultivated, the total volume of production and productivity has been registered for the past ten years. Regrettably, there has been no or little attention given to the postharvest management of the harvested produces, which concurrently brought about the loss of a third of what has been harvested before it reached the consumers. This is partly attributed to the absence of supporting institutions and policy framework that can advocate and provide service to different stakeholders engaged in the sector along the FSC. There appears to be lack of attention at all levels of the FSC including education, research, and extension and policy formulation with due attention towards the postharvest sector. The supporting institutions available in the study woredas (Annex Table 11-14) are providing loans and advice regarding inputs such as seeds, fertilizers, and other agrochemicals including herbicides and insecticides. To serve the purpose, there are microfinance institutions, primary cooperatives, cooperative Unions, credit and saving institutions for different crops other than sorghum.

To date, there are only very few institutional setups to support postharvest activities at the different segments of sorghum SC in Alamata Woreda. The study team noticed the support given by Food and Agricultural Organization (FAO), in collaboration with Melkassa Agricultural Research Center (MARC), in training Artisans, Development Agents (DAs) and farmers in the area of construction and use of metal silos. Like many other places, there is no access to credit specifically given for postharvest activities. However, loan for the purchase of agricultural inputs is provided by Dedebit Microfinance and Tigray Relief Association. Agricultural Transformation Agency (ATA) provides some support to promote the value chain of sorghum in the area. Alamata Agricultural Research Centre (AARC), one of the most recently established research centres, has not started providing technologies or advisory services pertaining to postharvest. Similarly, the relevant institutions and their respective roles in sorghum supply chain for the remaining three woredas are indicated in Annex Table 10-12 in the Annex part.

3.3.3 Overview of sorghum supply chains

Sorghum - supply chain in the different study woredas was found to be more or less similar. In West Armacho Woreda the main sorghum supply chain is indicated in Figure 17. In this woreda, 85,750 tons of sorghum is produced annually by 4,771 female and 8,319 male households (Table 30).

Of the total production of sorghum, 90% is consumed at the household level and the remaining 10% is marketed. In most cases, the final destination (market places) of the grain is the Woreda's town.

Table 30. Food Supply Chains of Sorghum in the Subsector for the four Woredas

FSC #	Geographical area of production (Woreda)	Final product	Volume of final product (ton/year)	Number & sex of smallholder producers	Market of final product, location, buyers	Project support
1	Alamata	Sorghum Grain	86,400.00	F=8,187 M=15,172	Grain sold in the local market of Alamata town	NA
2	West Armacho	Sorghum Grain	85,750.00	F=4,771 M=8,319	Most of the time traders come to the farmers' field and buy the grain at farm gate price.	NA
3	Derashe	Sorghum Grain	36,530.70	F =786 M= 15477	There are three local markets for sorghum: Gedole (woreda capital), Gato and Holte. Grain is also transported to distant places like Konso, Arba Minch and Wolaita Sodo contributing to national food security	NA
4	Fedis	Sorghum Grain	395,928.00	F= 1,234 M= 27,567	Fedis is not surplus producing woreda and often it has to cover its food deficit from other woredas	NA

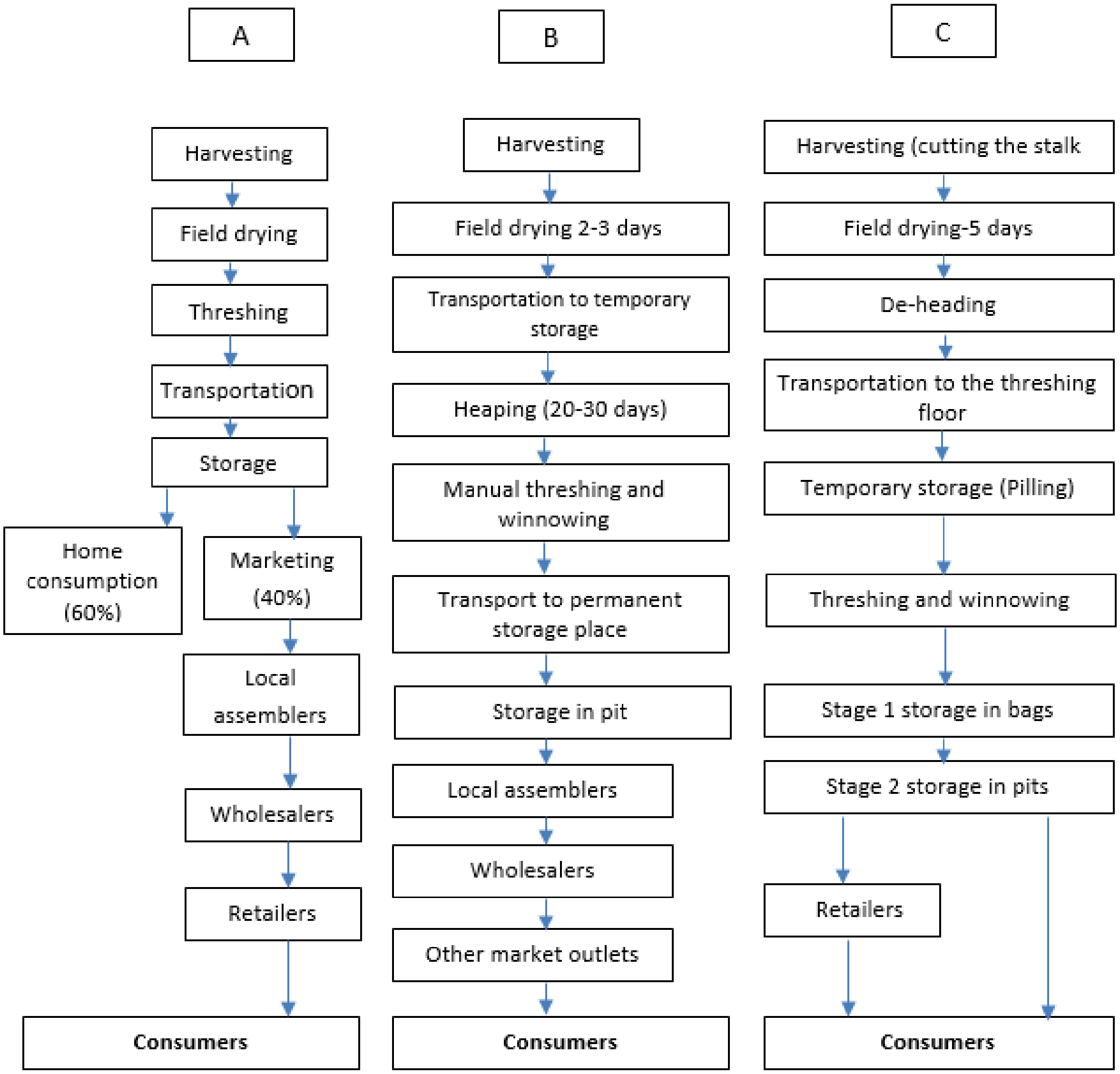


Figure 17. Sorghum supply chain (A): Alamata, (B): Derashe and (C): Fedis woredas

The national importance (economic, generation of foreign exchange, contribution to food consumption and nutrition, and environmental impact) of sorghum in all study Woredas except Derashe is very minimum (Table 31). Most of the sorghum grain produced in the three Woredas is consumed locally (in the same Woreda where it was produced) and its national contribution is minimal. However, sorghum produced in Derashe Woreda is transported to distant places like Konso, Arbaminchi and Walayita Sodo contributing to national food security.

Table 31. Importance of sorghum supply chains at national level

FSC # (Selected Woreda)	Economic Importance	Generation of foreign exchange	Contribution to national food consumption	Contribution to national nutrition	Environmental impact	Total score
Alamata	2	1	2	2	1	**8**
West Armacho	2	1	2	2	1	**8**
Derashe	3	1	3	3	1	**11**
Fedis	2	1	2	2	1	**8**

1= Low, 2 = Medium, 3= High

The main actors in the sorghum supply chain are the producers and the final consumers. Even though the contribution of sorghum to the national economy is very limited, its importance to the main actors of sorghum supply chain is commendable (Table 32). Sorghum production is more important in Derashe Woreda followed by Fedis and Alamacho woredas.

Table 32. Importance of Sorghum - in four selected woredas of Ethiopia

FSC # Selected Woreda	%age of produce by smallholders	Income generation	Involvement of the poor	Employment provision	Total score
Alamata	3	2	3	2	**10**
West Armacho	3	2	3	2	**10**
Derashe	3	3	3	2	**11**
Fedis	3	2	3	2	**10**

1= Low 2 = Medium 3= High

The preliminary screenings of qualitative and quantitative loss of sorghum in different postharvest chains are indicated in Table 33. Based on available literature information and experiences in the area, CLP and LLP are also indicated for each postharvest activity.

Table 33. Preliminary screening of food losses in the selected supply chain of Sorghum*

Steps in FSC	Expected Loss Points: Quantitative CLP / LLP	Expected Loss Points: Qualitative CLP / LLP	Comments and Remarks
FSC # Alamata woreda			
Harvesting	CLP	LLP	Due to shattering nature of varieties &delayed harvesting.
Field drying	CLP	LLP	Drying in the field exposes the crop to attack by weevil & rodents.
Transportation to threshing field	LLP	LLP	This is done with maximum care
Threshing	CLP	CLP	Grains are mixed with soil, dirt and cattle waste during threshing. There is spilling of grains at the time of threshing and winnowing
Storage	CLP	CLP	Damage by weevil, mould & rodents. Storage is traditional using underground pits, *gota* & *gotera*
Marketing	LLP	LLP	Handling is done with care
FSC # West Armacho Woreda			
Harvesting	CLP	LLP	Owing to the shattering nature of varieties
Field drying	CLP	LLP	Loss due to spillage & consumption by domestic animals & rodents
Transportation to threshing field	LLP	LLP	This is done with a maximum care
Threshing	CLP	CLP	Grains are mixed with soil, dirt & cattle waste during threshing which affects both grain quality & quantity. This is done on cow dung smeared floor called *awadima* with no tarpaulin or canvas.
Storage	CLP	CLP	Storage contributes the maximum loss of sorghum in the woreda due to damage by weevil, mould & rodents.
Marketing	LLP	LLP	Handling is done with care but sometimes there is an admixture with foreign matters
FSC # Derashe woreda			
Harvesting	CLP	LLP	High shattering percentage due to the nature of the local variety called *Kere*, delayed harvesting resulting in rotting of heads in the field and consumption by migratory birds called *Quelea quelea*
Field drying	LLP	LLP	High seed shattering due to extended drying period & untimely rain
Transportation to threshing field	LLP	LLP	Almost no loss due to good transportation practice
Threshing	LLP	CLP	Grains are mixed with soil, dirt and cattle waste as the task is done on bare ground with no canvas or tarpaulin lining
Storage	CLP	CLP	Damage due to insect pests and mould. Chemicals should be used to control storage insects
Marketing	LLP	LLP	Handling is done with care
FSC # Fedis woreda			
Harvesting	CLP	LLP	High shattering susceptibility of the local sorghum variety
Field drying	LLP	LLP	
Transportation to threshing field	LLP	LLP	Almost no loss due to good transportation practice
Threshing	CLP	CLP	Grains are mixed with soil, dirt & cattle waste. Loss due to spillage.
Storage	CLP	CLP	Usually, grains are stored in an underground pit where damage occurs due to insect pests and mould.
Marketing	LLP	LLP	Handling is done with care

**This table is prepared from available literature information.*

3.3.3. Major supply chain of sorghum-Situation analysis

3.3.3.1. Description of the major supply chain

Sorghum is a commodity, which is mainly consumed by the producers at the household level. Thus the major sorghum SC goes from production-harvesting-threshing-transportation-storage, marketing via wholesale and retail finally reaching home consumption (Figure 18). Sorghum as a grain crop passes through different postharvest steps to the final consumption. Estimated duration of each step and product type obtained with their conversion factors are indicated in Table 34.

Table 34. Steps and Products in Sorghum Supply Chain

Process	Duration	Product out	Weight from 100%	Conversion Factor
Stored grains	2 -8 weeks	Sorghum grains	100	1
Primary assemblers	2-5 days	Sorghum grains	100	1
Wholesalers	2-3 weeks	Sorghum grains	100	1
Retailers	2-4 weeks	Sorghum grains	100	1
Processors (local milling)	1 day	Sorghum Flour	90	1.11

3.3.3.2. Description of the existing marketing systems

Alamata woreda

Market places and mode of transport

Marketing systems of sorghum in the study Woredas is more or less the same. For example, farmers mainly sell sorghum to local consumers in Alamata town. The supply of sorghum to distant market is not common since sorghum is not regarded as an industrial or export crop. It is considered as a major crop and used for both home consumption and marketing at local and nearby markets. Information obtained at the KII shows that from the total produce of sorghum about 40% was sold while the remaining 60% was consumed at household level in Alamata Woreda.

Market price and form of product

During the study period, the market survey year the average price range was from 23.4 to 35 USD/ 100 kg thus the average being 29.3 USD/ 100 kg. Often farmers sell their produce immediately after harvest to fulfil household obligations like wedding and settle input depts. The study found that majority of farmers sell sorghum during December and January every year and most of the farmers sell their grains at Alamata town. Majority of the farmers sell their produce to traders and local consumers. The community mainly uses sorghum for consumption in the form of *enjera*, bread and *Tella*. It was also observed that marketing cooperatives do not exist for this crop in Alamata Woreda.

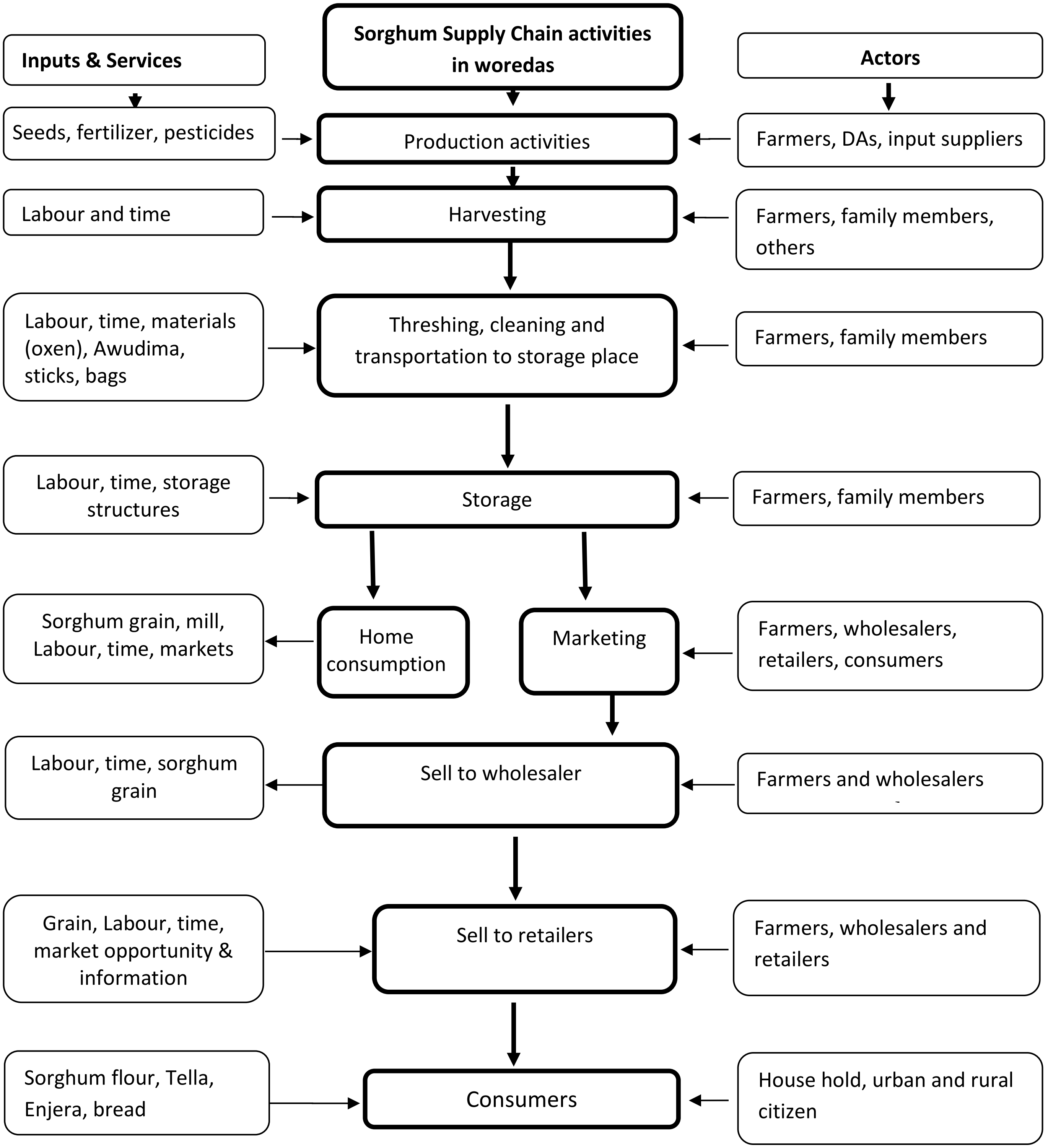


Figure 18. Flow diagram depicting the major supply chains and marketing systems of sorghum in four sorghum producing woredas of Ethiopia.

Market information

The attention given to sorghum in relation to the other cereals such as maize and wheat is low. As a result marketing services related to sorghum production are scant. Most often farmers collect market information and specifically about the price of sorghum from their neighbours and through market observation. On the overall, market information services for sorghum are obtained mainly through informal institutions.

Major market problems

The major marketing problems of sorghum in Alamata Woreda are related to poor quality sorghum grain due to mould infection caused by moisture seepage during underground storage and low price of sorghum as most farmers sell their product after harvest at the same time leading to a market glut.

West Armacho Woreda

Market places and mode of transport

Similarly, in west Armacho Woreda of Amhara regional state, from the total sorghum produced only 10% is marketed and the remaining is used for household consumption, while the national estimation on the amount of sorghum marketed is about 11.5% (FAO, 2013). Most of the time traders come to the farmers' field and buy at farm gate price.

Market price and form of product

During the survey year, the maximum and minimum price of 100 kg sorghum was approximately 34.1USD and 14.6 USD respectively. The marketing system for sorghum in Ethiopia is poorly developed and has a limited industrial use (FAO, 2013). There are different forms of products consumed in the woreda. Almost 50% of sorghum is consumed in the form of *enjera*, 5% as *Tella* (local Beer) and bread, with the remaining 45% used as porridge.

Market information

In West Armacho woreda there are meagre market information services regarding sorghum in the woreda. Information is obtained from farmers, bureau of agriculture, and intermediaries.

Major market problems

There are smallscale women's associations which are engaged in petty trading like making *enjera*, *tella* etc. Lack of sorghum processing firms and limited market information remain fundamental problems in marketing of sorghum in west Armacho woreda.

Derashe Woreda

Market places and mode of transport

Derashe is one of the surpluses sorghum producing woredas. Sorghum production in the woreda is for both home consumption and market. From the estimated total volume of production 36,530.7 tons/yr, 65% is for consumption, 32% is marketed and 3% is used as a seed for the next growing season.

Derashe woreda administration has established three local market places where farmers bring sorghum for sale. These markets are in Gedole (woreda capital), Gato and Holte. Each place has its own market day once in a week. It is not allowed to sell or buy sorghum out of these days in the fixed places. The local assemblers move to these three places to buy the sorghum. They buy during the day time and transport on the same day to other places (Konso, Arbaminch and Sodo) during the night to reduce cost by avoiding warehouse rent. Almost all farmers use donkeys to transport their product to the market. But in absence of donkeys, women are responsible to take the product to the market. Other modes of transport are not used by sorghum traders in the Woreda, though there are medium road quality and medium transport facilities in the woreda.

There are different supply chains of sorghum market in the woreda. As indicated in sorghum supply chain of the Woreda, the supply chains are 'producers to consumers', 'producers to retailers' and 'producers to wholesalers (through local assemblers)'. The market shares of each chain actor are 75% direct to consumers, 10% to retailers, and 25% to wholesalers. There is no marketing service by the primary cooperatives, as cooperatives are not well established in the woreda.

Market price and form of product

Price of Sorghum varies across the various seasons of the year. In 2014/15, the average price of a 100kg of sorghum, calculated from one year monthly prices, was 19.12 USD/ 100 kg. The maximum price of a 100kg of sorghum during May and June in the production year 2014/15 was 26.83 USD/ 100 kg while the minimum price was 12.20 USD/ 100 kg from August to September. Whole grain sorghum is the only form of - product sold by the farmers.

Market information

Access to market information in Derashe woreda is a bit different from other woredas. Since there is a quota system on the marketing of sorghum (the amount of sorghum sold by one farmer on each market is fixed but varies from time to time), the woreda council will transmit the information to the farmers through the administrative structures. Other sources of market information are the agriculture office of the woreda and radios (FM in Awassa, National Radio, radio Fana and others).

Major market problems

The major market problems in Derashe woreda are:

i. *Lack of free market*: The quota system is imposed on sorghum marketing by the woreda administration and the municipality of Gedole. Both farmers, producers and traders have no freedom to sell and buy produce at their convenient time and place. The other problem is the issue of the quota system which limits the traders to buy crops from a limited geographic/market places beyond which they are not allowed to go. This has created an opportunity for some traders to set unfair prices. The sense of competition is not evident in such market system and farmers are not paid for their efforts.

ii. *Price fluctuation*: price varied from 12.2-26.8 USD/ 100 kg because often farmers sell sorghum immediately after harvest, which leads to low price and vice versa.

iii. Cultural influences: the cultural influence is to denote the way exchange happens in the woreda. When farmers take their product to the market practically they do not have the right to measure/weigh and sale their product. The buyer/assembler has a full right to bring his/her own measuring container, which is unfairly modified to hold more than the normal volume and significantly make a difference between farmers expectation and buyer estimation. For example, when they use a can (usually of 'Merti tomato paste can') as a weight/measuring equipment; they modify the volume of the can by bulging the bottom and side of the wall to measure more volume but they pay the price for the normal can size.

Fedis Woreda

Market places and mode of transport

Fedis is another main sorghum producing woredas in Ethiopia. However, unlike the other woredas, it is not a surplus producer supplying to other neighbouring markets. The crops are planted both for consumption and marketing purpose, though the proportion for the market is very small. From the total volume (39,592.8 tons/year for 2014/15 production season), 10% is supplied to the local market and 5% is kept for seed. The remaining 85% is locally consumed at the household level. On the contrary, during fair or bad harvest seasons, there is demand for more sorghum from other surplus-producing parts of the country. Unlike other woredas and other crops, there is no long distance market place for sorghum in Fedis woreda. What is produced is consumed in the woreda, and hence the local retail market is the only market destination for producers and consumers with minor involvement of intermediaries or retailers.

There are only two different supply chains for sorghum marketing in the woreda; producers to retailers and producers to consumers. The market shares of each chain actor are 10% and 90% respectively. There is no marketing service by the primary farmers' cooperatives.

Market price and form of product

Price of sorghum varied across different months of the year. The average price of a 100kg of sorghum in 2014/15 production year was 30.9 USD /100 kg. The maximum price of a 100kg of sorghum in 2014/15 was 36.6 USD/ 100 kg and remained the same from September to December while the minimum price was 23.2 USD/100 during the month of January.

Market information

With regard to the market information retrieval system, access to market information in Fedis woreda is similar to other woredas. Sources of market information include radio, cell phones, woreda agriculture office and Kebele agricultural extension workers. But not all of these sources are used by farmers because sorghum is not a priority cash crop. 'Chat' (Khat) and groundnut are priority cash crops and farmers are more alert on their price than sorghum.

Major market problems

Major market problems in Fedis Woreda are low price offer from buyers, poor market chain, and low consumer demand for the crop immediately after harvest.

In general, the sorghum in Derashe is produced mainly for household consumption with very much simplified SC linked with little input, services providers and actors as described in Figure 17.

3.3.3.3. Gender Role in PHM

Generally, it has been estimated that women produce between 60% to 80% of the food in most developing countries and are responsible for half of the world's food production. Nowadays their key role as food producers and critical contribution to household food security is being recognized (Hassan, 2010). Thus, attention to gender relations and roles in postharvest management is crucial.

Alamata Woreda: It was noted that men dominate the decision-making process regarding postharvest management issues and they equally control income obtained from the sales of crops. Men play a major role in decision-making in 81.81% of the operations while women take decisions for only 18.18% of postharvest activities. On the other hand, in addition to their reproductive role, women exclusively undertake to process of sorghum. However, despite their household responsibilities and involvement in the processing of sorghum they don't have a role in managing the income and deciding the use of money.

West Aramacho woreda: In West Armacho, the role of men and women varies in sorghum PHM. The main tasks of women are preparing sorghum grain for home consumption, participating in harvesting and processing whereas men control selling and the income thereof in addition to their roles in the field. This is situation is similar to Alamata.

Derashe Woreda: Participation of men and women in PHM of sorghum grains in Darashe woreda of Segen people in SNNPR seemed equal as reflected in the FGD in the presence of both male and female participants. However, when female participants were asked in the absence of male participant, they revealed the absence of gender equality in the Woreda. Heavy tasks are the responsibility of women e.g. in the absence of donkeys, women transport sorghum on their back to the market. On the other hand, men take the marketing role only if donkeys are available for transportation. In general, there is more pressure on women in threshing floor preparation, fetching water, grinding of grains, preparation of food and other home tasks while men control of marketing of sorghum and income thereof.

Fedis Woreda: Female farmers revealed the absence of gender equality in the Woreda. Heavy tasks are the responsibility of women and resources are much more controlled by men/husband. Men dominate some activities while women do others. There are also post-harvest activities equally operated by both men and women. The detailed analysis of gender role in the different PHM of sorghum in the four study woredas is indicated in Table 35.

Table 35. Detailed description of the food supply chain – Social structures

FSC STEPS	Women				Men				Gender /social patterns Additional observations and remarks
	AL	WA	DR	FD	AL	WA	DR	FD	
Primary production	2	2	2	2	3	3	3	3	Men decide on when and how much to produce. They are responsible for preparing land, sowing seeds, and weed control especially chemical spraying while women are responsible for weeding, bird watching in addition to their reproductive roles, food preparation, water fetching and child caring.
Harvest	2	2	2	3	3	3	3	3	Harvesting of sorghum is done jointly by men, women and children.
Field stacking	3	2	2	2	3	3	3	3	Same as above but men dominate this work as it may require climbing
Transporting to threshing field	3	3	3	3	2	2	2	2	Commonly this is done by women and children though men are often involved
Threshing and winnowing	2	2	2	2	3	3	3	3	Threshing is done by men while winnowing, which is laborious tossing of the threshed product to separate from the chaff, involves both men and women
Transport to storage place	3	3	3	3	2	2	2	1	With small volume usually women & children do take the responsibility while for bulk transportation which usually requires pack animals, men will be involved.
Construction of storage structures	2	2	2	2	3	2	2	1	Outdoor structures such as Gotera are commonly constructed (the main structure) by men & plastering is done by women. For indoor structures such as Gota, women and children take the major role in constructing and plastering it.
Storage	3	3	3	2	2	1	1	1	Women are responsible for cleaning storage structures & storing grains.
Transportation to market & sale	2	2	2	2	1	1	1	1	Though the whole family get involved in transporting sorghum to the market men often involve when the volume is large & transportation is using pack animals or vehicles (rarely). Small volumes are carried by women & children assist them
Agro-processing	0	0	0	0	2	2	2	2	At local mill, no women are operating machines.
Storage in wholesale warehouses	0	0	0	0	3	3	3	3	This is entirely dominated by men for the mere reason that it is physically demanding job
Wholesale trade	0	0	0	0	3	3	3	2	Exclusively men dominated since a large volume of trade by women is considered as a risky business and from culture and religion points of views. Fedis is not a surplus producer and obtains grains from other woredas to compensate for its deficit.
Retailing	2	3	3	2	2	2	1	1	Both men and women can do retail though men do tend to take the upper hand in order to control the income.
Seed cleaning & storage	3	3	3	3	1	1	1	0	Entirely done by women since sorting is considered as women's job. However, some men do help in this task.
Processing/ grinding, baking	3	3	3	3	0	0	0	0	Women involve entirely in processing and cooking for family consumption. In this case, grown-up children help their mothers. Women always take the responsibility to prepare food and feed the whole family.

Treatment/ chemical application & Pest Control	2	2	2	1	2	2	2	2	Pre-harvest application of chemicals for the control of weeds, diseases & insect pests is the responsibility of men. However, the control of rodents with traps & cats is often undertaken by women. Application of storage chemicals such as actellic and phostoxin is done by men.
Total score	**31**	**31**	**31**	**29**	**35**	**33**	**32**	**28**	
% share	**64.6**	**64.6**	**64.6**	**60.4**	**72.9**	**68.8**	**66.7**	**58.3**	

***3 =** High role, **2** =Medium role, **1**=Low role, **0** = no role, AL=Alamata, WA=West Armacho, DR= Derashe, FD=Fedis*

In general, women in addition to their reproductive and social roles, participate almost equally = in pre and postharvest operations of sorghum production. They are extremely busy with cleaning, transportation, storage and retail of grains while men often dominate in the wholesale market. The household processing is entirely shouldered by women while the agro-processing operations especially those using machines such as milling are such as operating taken as the local mills, is completely run by men.

3.3.4. PHL of sorghum - Study findings

Increasing agricultural productivity is critical for ensuring global food security, but this may not be sufficient. To sustainably achieve the goals of food security, food availability needs to be increased through reductions in food losses at all levels of the SC. Therefore, assessment of food loss at all stages of postharvest handling in sorghum supply chain is crucial to design appropriate interventions to combat food loss at the critical loss points.

3.3.4.1. Sorghum loss: risk factors

The extent and types of postharvest losses in sorghum are attributed to many factors including the nature of the crop, the environmental condition during production and subsequent handling after harvest. Type of technology and level of production determine the amount of grain to be stored for a given period. There are optimum conditions that could extend the shelf life and reduce the loss of produces in terms of quantity and quality. Any condition, which deviates from the optimum is a risk factor that leads to increased postharvest losses. The risk factors contributing to the existing an acceptably high postharvest loss in sorghum are given in Table 32. Growers in the study woreda do not have varieties of sorghum that are resistant to shattering, damage by birds, insect pests and diseases. This coupled with poor implementation of Good Agricultural Practices, unavailability of affordable postharvest technologies, and use of traditional and inefficient processing and storage facilities put sorghum at risk for qualitative and quantitative losses. Distance from the market, limited market information and poor price discrimination for better quality products inadvertently provide producers with little or no incentive to practice appropriate postharvest management practices. There is variation in the observed postharvest loss along the supply chain and the associated causes for the losses. The total postharvest loss in sorghum ranged from 29.8% in West Armacho to 35.7% in Alamata based on the current study results. This amount of loss is said to be high and is caused by several - factors collectively named as risk factors. The risk factors contributing to estimated losses are: (i) rainfall leading to moisture (fungi infection) (ii) poor agricultural practices disposing the grains to several damages like insect pest infestation (iii) pathogen infection (iv) damage by rodents (v) birds and domestic animals (vi) surplus production leading to extended period storing (vii), poor storage structure (viii) poor management and handling technologies (ix) limited price incentive and others (Table 36).

Table 36. Sorghum Food Loss Risk Factors for Four Woredas (AL, WA, DR and FD)

Variable	Unit	Relation to food losses contributing to low losses	Value of variable (observed in the case study)			
			AL	WA	DR	FD
Crop variety	Y/N	Varieties resistant to shattering, insect, diseases	N	N	N	N
Good Agricultural Practices (GAP)	Y/N	Yes	N	N	N	N

Rainfall during production	Y/N	Optimum (Opt) range	N	N	Y	N
Production supply/ demand ratio	Ratio	< 1	>1	>1	>1	>1
Rainfall during Postharvest phase	L/M/H	Low rainfall	L	L	L	L
Postharvest technology	L/M/H	High	L	L	L	L
POs / Coops	Y/N	Yes	N	N	N	N
Processing technology	L/M/H	High	L	L	L	L
Good Manufacturing Practices (GMP)	Y/N	Yes	N	N	N	N
Packaging materials and facilities	L/M/H	High	L	L	L	L
Storage conditions	L/M/H	High	L	L	L	L
Transport duration	Hour	Low duration (<1 h)	1.5-3	1-3	1-2	1-2.5
Market information	L/M/H	High	L	L	L	L
Price incentive for quality	Y/N	Yes	N	N	N	N
Knowledge of FSC actors	L/M/H	High	L	L	L	L
Consumer access to food product	L/M/H	High	L	L	L	L

Legend: Y/N = Yes / No; L/M/H = Low / Medium / High. AL = Alamata, WA=West Armacho, DR = Derashe, FD=Fedis

3.3.4.2. Observed Postharvest Loss (PHL) and Critical Loss Points (CLP)

Like many other crops, sorghum incurs postharvest losses in terms of both quality and quantity. However, the extents of postharvest loss at each stage of the sorghum supply chain vary from place to place and time to time. It also varies at along the supply chain. The extent of PHL, CLP and LLP in sorghum for the four study Woredas are indicated in Table 37-40 and briefly described for each Woreda as follows.

In Alamata Woreda of Tigray Regional State, the total postharvest loss in sorghum, based on the FGD, KII and field observations, ranged between 28.8% and 42.75 % respectively. The average total sorghum loss is 35.7%. The critical loss points of sorghum in Alamata Woreda are storage, threshing and harvesting stages. Detailed data are shown in Table 37.

Similarly, the in west Armacho woreda of the Amhara regional state, the total post-harvest loss in sorghum estimated ranged between 26.50% and 33.00 % the average being 29.75%. The critical loss points of sorghum in West Armacho woreda are during drying, storage and harvesting stages. Estimated postharvest losses for each activity are included in Table 38.

Similarly, harvesting and storage are the two major CLPs of sorghum in Derashe woreda (Table 39). With The losses in this woreda are associated with high rate of shattering due to with the use of local varieties which are susceptible to shattering and poor harvesting practice, rotting on the field due to untimely rain (local variety "*Kere*" is more susceptible) and birds damage (migratory birds - *Quelea quelea*) due to late harvesting. In general, harvesting and storage are the two major steps contributing to the loss of large volume of sorghum in this woreda.

Finally, based on the nature of sorghum variety cultivated in Fedis woreda, the maximum amount of loss was experienced during harvesting of the head with a stalk at field level, threshing and winnowing of heads and storage in the underground pit (Table 40). The total sorghum grain loss in Fedis Woreda was estimated at 33.2% of the potential yield that could be harvested. The high loss of the stored grains is attributed to damages by weevils. Moreover, loses due to mould infestation of stored grains (often during pit storage) (Figure 19) and losses during field drying (Figure 20) contribute to the high percentage of postharvest losses of sorghum in Fedis Woreda. Thus the CLP of sorghum grain in Fedis Woreda were identified to be harvesting, threshing/winnowing and storage period. This calls for future intervention efforts to focus on these stages without leaving the LLP. In a nutshell, annually, an estimated 35.7%, 29.8%, 32.6% and 33.2% of the total production of sorghum is lost after harvest in Alamata, West Armacho, Derashe and Fedis Woreda respectively (Table 37-40).

Figure 19. A huge underground pit for sorghum storage in Fedis

Figure 20. Field storage of sorghum heads storage and shattering loss of grains

3.3.4.3. Causes of losses and identified loss reduction measures

Postharvest losses of grain crops vary greatly among commodities, production areas and seasons. As a product moves along the postharvest chain, PHLs may be caused by several loss causing factors such as improper handling or bio-deterioration by microorganisms, insects, rodents or birds damage (Victor, 2014). Besides, losses could be attributed - to other factors such as high moisture content of grain before storage; traditional methods of harvesting, drying, threshing and storage as well as the practices of leaving grains in the field for extended period exposing it to rain, rat, insect pests infestation, pathogen infection, wild and domestic animals damage. Generally, internal factors including all PH activities along the supply chain and external factors including environmental and socio-economic are the cause of post-harvest loss. These root causes of postharvest sorghum grain loss could be reduced if proper management and handling strategies are developed and implemented. Proper drying after harvest and before storage and avoiding moisture seepage in storage pits reduces mould development and infection by fungi. Use of controlled atmosphere in storage especially ensuring that is well aerated and ventilated reduces the infection and infestation caused by pathogens and insect pests respectively. Well-aerated and ventilated storage structures reduce the impact of pests. Proper handling and avoiding mechanical damage at each stage of SC reduces the mechanical loss of sorghum grain during transportation, threshing, winnowing, etc. Please refer to causes findings in Annex Figure 1 for the summarized view and identified major causes at different levels.

3.3.4.4. Low Loss Points (LLP) and good practices

Low loss Points (LLP) for sorghum in each woreda along the SC are identified and indicated in Table 37-40. Such LLP could be attributed to the limited time the product stayed at that particular stage and the good management practices farmers implemented. At different segments/stages of the supply chain, there are presumed losses caused by different biotic and abiotic loss incurring factors. Corresponding LLPs for each postharvest activity in the selected woredas also indicated in the same tables. Farmers have their indigenous knowledge of managing grain crops. They use resistant varieties, admix different grains, apply pesticides, and use different mechanical pest management tools.

Table 37. Summary Result Matrix of Sorghum Losses of Alamata Woreda

FSC stage/ process	Type of loss QN./QL	%age lost in this process QN	%age product that incurred QL loss in this process	%age product that goes through this stage	%age loss in the FSC	Cause of loss/ Reason for low loss	Reduced market value	CLP / LLP	Destination of food loss	Impact/ FSC actors affected (M/F)	Loss perception of FSC actors (M/F)	Suggested solutions
Harvesting	QN	8.25		100	8.25	High shattering, late harvesting Shattering loss and seepage loss		CLP	Consumed	Farmers	High	- Care during harvesting - Care during transportation, and use of good transportation facility - Use of improved mobile thresher machine or hand threshers Care & pest management
	QL		**0**		0		0					
Transportation	QN	2.0		91.75	1.84	Poor handling& pests Storage pests		LLP	Consumed	Farmers	Low	
	QL		0		0		0					
Threshing /Winnowing	QN	9.15		89.75	8.24	Non High shattering, late harvesting		CLP	Consumed	Farmers	High	
	QL		**2**		1.8		1.8					
Storage	QN	11.7		78.6	9.13	Shattering loss and seepage loss Poor handling& pests		CLP	Consumed	Farmers	High	
	QL		**2**		1.56		1.56					
Marketing	QN	Almost Nil	Almost Nil	66.9	Almost Nil	Storage pests		LLP	Consumed	Farmers		
	QL	Almost Nil	Almost Nil		Almost Nil		Nil					

Table 38. Summary Result Matrix of Sorghum Losses of West Armacho Woreda

FSC stage/ process	Type of loss QN/ QL	%age lost in this process /QN/	% of the product incurred QL in this process	% of product goes through this stage	%age loss in the FSC	Cause of loss/ Reason for low loss	Reduced market value (%)	CLP / LLP	Destination of QL food loss (discard, consumption, sale)	FSC actors affected (men / women)	Impact of PHL at the FSC	Loss perception of FSC actors (men/women)	Suggested solutions
Harvesting/ Uprooting	QN	4.0		100	4.0	High shattering, late harvesting Shattering loss and seepage loss		CLP	consumed	Farmers	income	less concern	- Care during harvesting, harvest on optimum time - Proper field drying - Care during loading and unloading as well as transportation - Use of improved mobile threshers - Pest management
	QL		0		0		0						
Field drying / Stacking	QN	14.1		96	14.1	Poor handling & pests		CLP	consumed	Farmers	income	less concern	
	QL		0		0		0						
Transportation to threshing field	QN	1.0		81.9	1.0	Storage pests		LLP	consumed	Farmers	income	less concern	
	QL		0		0		0						
Threshing & winnowing	QN	2.3		78.8	3.1	High shattering, late harvesting		LLP	consumed	Farmers	income	Threshing and winnowing	
	QL		0.8		0.63		0.63						
Storage	QN	5.25		71.25	7.58	Storage pests		CLP	consumed	Farmers	income	-	
	QL		2.3		1.64		1.64						
Marketing & processing	QN/QL	Almost Nil	Almost Nil	71.25			-	-	-	-	-	-	

Table 39. Summary Result Matrix of Sorghum Losses of Derashe Woreda

FSC stage/ process	Type of loss QN/QL	%age lost in this process Quant	% product that incurred quality loss in the process	%product that goes through this stage	%age loss in the FSC QN+QL	Cause of loss/ Reason for low loss	Reduced market value	CLP / LLP	Destination of food loss	Impact/ FSC actors affected (men / women)	Loss perception of FSC actors (men / women)	Suggested solutions
Harvesting	QN	15.6		100	15.6	High shattering due to aggressive harvesting	15.6	CLP	consumed	Farmers	High	- Avoid aggressive harvesting and harvest on optimum time - Minimize shattering loss and shorten field drying time - Protect from animals and theft - Protect from animals and theft - Avoid seepage and scattering loss, use mobile threshers - Reduce height of winnowing, avoid winnowing when there is strong wind - Care during transportation - Pest management
	QL		0		0							
Field Drying	QN	1.8		84.4	1.8	Shattering and wild and domestic animals attack	1.8	LLP	consumed	Farmers	low	
	QL		0		0							
Transportation to pilling site	QN	0.30		82.6	0.3	Seepage loss due to shattering, theft	0.3	LLP	consumed	Farmers	low	
	QL		nil		0							
Field temporary storage	QN	0.94		82.3	0.94	Pests and theft	0.94	LLP	consumed	Farmers	low	
	QL		nil		0							
Threshing	QN	2.0		81.36	2.4	Scattering and admix with foreign body	2.4	LLP	consumed	Farmers	low	
	QL		0.4		0.33		0.33					
Winnowing	QN	0.94		78.96	0.94	Scattering loss	0.94	LLP	consumed	Farmers	low	
	QL		Nil		0		0					
Transportation to storage site	QN	0.09		78.02	0.09	Seepage loss due to holes on the polypropylene bags	0.09	LLP	consumed	Farmers	low	
	QL		Nil									
Storage	QN	8.9		67.37	10.65	Pest damage	10.65	CLP	consumed	Farmers	high	
	QL		1.75				1.18					
Marketing	QN/QL	Negligible	Negligible				0	LLP				

Table 40. Summary Result Matrix of Sorghum Losses of Fedis Woreda

FSC stage/ process	Type of loss Qn./Ql	%age lost in this process Quant	%age product that incurred quality loss in this process	%age product that goes through this stage	%age loss in the FSC	Cause of loss/ Reason for low loss	Reduced market value	CLP / LLP	Destination of food loss	Impact/ FSC actors affected (men / women)	Loss perception of FSC actors (men / women)	Suggested solutions
Harvesting	QN	7.03		100	7.03	High shattering due to aggressive harvesting		CLP	Consumption	Farmers	High	- Avoid aggressive harvesting and harvest on optimum time - Minimize shattering loss and shorten field drying time - Protect from animals and theft - Protect from animals and theft - Avoid seepage and scattering loss, use mobile threshers - Reduce height of winnowing, avoid winnowing when there is strong wind - Care during transportation - Pest management
	QL		0		0		0					
Field Drying	QN	3.16		92.97	3.16	Shattering and wild and domestic animals attack		LLP	Consumption	Farmers	low	
	QL		0		0		0					
De-heading	QN	1.33		89.81	1.33	Seepage loss due to shattering, theft		LLP	Consumption	Farmers	low	
	QL		0		0		0					
Transportation to threshing site	QN	1.52		88.48	1.52	Pests and theft		LLP	Consumption	Farmers	low	
	QL		0		0		0					
Field temporary storage	QN	0.63		86.96	0.63	Scattering and admix with foreign body		LLP	Consumption	Farmers	low	
	QL		0		0		0					
Threshing /winnowing	QN	5.53		86.33	5.33	Scattering loss		CLP	Consumption	Farmers	High	
	QL		1.65		1.65		1.65					
Transportation to storage site	QN	0.03		79.15	0.03	Seepage loss due to holes in the polypropylene bags		LLP	Consumption	Farmers	low	
	QL		0		0		0					
Storage	QN	10.92		79.12	10.92	Pest damage		CLP	Consumption	Farmers	high	
	QL		2.3		2.3		2.3					
Marketing	Negligible	Negligible		65.9				LLP				

3.3.5. Sorghum loss reduction strategy-Conclusions and recommendations

3.3.5.1. Impact of sorghum losses

Economic impact

The impact of Postharvest loss in sorghum can be discussed from economic, environmental, and food security perspectives. Considering the average of 32.8% postharvest loss registered in the four woredas, it can be estimated that a total of 170,615.30 tons of sorghum and more than USD 12 million per annum has been lost in the supply chain.

Impact on nutrition and food security

As indicated in Table 41, the postharvest loss of sorghum in Fedis, Derashe, Armachiho and Alamata resulted in a loss of 703M kcal of food. If we consider 1,820 kilocalories per person per day (Schmidt and Dorosh, 2009), with an estimated loss of sorghum only from the four woredas resulted, it is a a net loss of energy for more than 386, 000 adults. Since Sorghum is one of the good sources of carbohydrates, both quantitative and qualitative losses will contribute food and nutritional insecurity.

Impact on the environment

Assuming an average productivity of 3.40 tons per ha as indicated in Table 41, total loss of 156,023.55 tons is equivalent to the volume of sorghum that could be produced from 45,889.28 ha land (total loss divided by productivity per ha). In addition to wastage of the land, there were losses of other resources like water, air, and agricultural inputs and so on to produce this volume of lost sorghum at different postharvest steps.

Table 41. Post-harvest Loss of Sorghum in Four Producing Woredas in Ethiopia

Woreda	Percent weighted loss (%)	Total production (tons/year)	Weighted loss (tons/year)	Price of grain per ton per woreda (USD)	Loss in Monetary Value (USD/yr)	Productivity of crop (tons/ha)	Loss of cultivated land (ha) due to PHL	Caloric value loss (kcal/yr) Billion
Alamata	29.70	86,400.00	25,672.20	309.00	7,932,711.28	2.40	10,696.80	8.70
Derashe	28.60	85,750.00	24,560.00	191.00	4,690,955.18	2.95	8,325.40	8.33
W. Armacho	25.50	36,530.70	9,325.00	219.50	2,046,839.51	2.50	3,730.00	3.16
Fedis	28.10	395,928.00	111,058.10	292.70	32,506,716.58	4.80	23,137.10	37.65
Total	**-**	**604,608.70**	**170,615.33**	**-**	**47,177,222.55**	**-**	**45,889.30**	**57.84**
Mean	**27.40**	**518208.70**	**42653.83**	**253. 05**	**11794305.64**	**3.40**	**11472.33**	**14.46**

The high loss is also a source of disappointment and moral damage for farmers. Low or fluctuating market price, together with the high rate of loss make farmers less motivated to produce more crop- in subsequent seasons. However, losses due to transportation and storage are not as such significant since transportation is done with maximum care and there is no more storage for an extended period.

3.3.5.2. Required inputs and cost-benefit analysis of sorghum loss reduction measures

Loss due to harvesting and storage is very high in sorghum supply chain. Minimizing these losses is essential to reduce PHLs of sorghum. So far, no mechanized harvesting practices are reported for sorghum. This might be due to ragged topography of fragmented farms and less price of the crop, which is not profitable to get a combine harvester service. Therefore, at this stage, it is only necessary to recommend that a good care during harvesting time is essential to avoid shattering of grains. The other CLP storage where losses due to failure in drying grains before storing the use of storage structures that hardly protect the grains from damage by storage insect pests, rodents and moisture migration have been reported as one of the biggest challenges. To minimize the loss in the supply chain farmers can use improved storage technologies like hermetic bags and galvanized metal silos. With the expectation to reduce storage-related losses by 95%, using hermetic bags like grain pro or PICS bag impact of storage insects can be significantly controlled. The cost-benefit analysis calculation (Annex Table 15) shows that the profitability of these bags is around 37 USD per year. That means by using these bags farmers can gain 37.7 USD per year reducing and losses. It is also possible to use galvanized metal silo as a storage structure. However, due to the current high price of the metal silos (219.5 USD for one-ton capacity), its profitability as a solution is 5.2 USD per year (Annex Table 16). However, if the price of metal silos is reduced to 150 USD through different government incentive schemes, profit can be generated through a reduced or no storage-related loss.

These are technologies recommended at household levels, but there are also other technologies, which can be used during harvesting, transportation, and threshing. Such type of technologies can be provided at the communal level or with the help of farmers cooperatives/unions since they are not profitable at a household level unless and otherwise they are rented for other farmers.

3.3.5.3. Sorghum loss reduction plan and strategy

Post-harvest loss reduction initiatives comprise of various technologies and practices used by the farmer, farmers' groups or cooperatives when handling the crops from harvest to its final destination. They include storing, transporting, cleaning, sorting, processing and packing.

Farmers in the study woredas use different cultural practices for sorghum postharvest loss reduction mechanism following each PH activities. Farmers are careful in making sure that they harvest their crop when it is well- matured and collect sorghum heads to one place to avoid wastage during harvesting. During this activity, sorghum heads are well dry and thresh to minimize threshing loss. Farmers use underground pits (in Alamata and Derashe woredas) for storing sorghum grains as one of the approaches for postharvest loss reduction. According to farmers’ perception, underground pit storage avoids storage insect pest infestation (such as weevils) and fire outbreak problem in the area- But the problem is there are leakages of air and moisture intothe pit, which causes significant losses of grains. Furthermore, farmers in the study area used improved and well-ventilated outdoor storage structures, which are placed above ground. Such types of storage structures can reduce mould development, which is very common in underground pit storage structure. However, the issue of damage by weevil in these kinds of stores was reported to be high. Therefore, it is necessary to develop an improved storage structures by optimizing the limitations and opportunities of both storage methods. Generally, respondents suggested adopting improved storage technology; capacity building of producers, experts and all actors along the chain via awareness creation and training program that are essential steps to reduce postharvest loss.

In designing food loss reduction strategies, it happens to be critical to consider the root causes of postharvest losses. It is very pertinent that structural as well as technical arrangements are crucial from the perspective of establishing a sustainable and robust postharvest system in the country. Sorghum, being one of the strategic crops in the country for reasons such as drought tolerance, wide genetic diversity available in the country and role of the crop as one of the staple crops for the wider population in the country, deserves due attention in terms of postharvest loss reduction and value addition interventions. The selection of any intervention strategy for sorghum should take due consideration of the treat from birds, shattering and damage during storage by insects and mould. This calls for a thorough analysis of available options before drawing recommendations. The following postharvest strategies and measures are put forward as possible recommendations to reduce postharvest losses.

Use of moisture meters: Farmers have very little options of knowing the moisture content of sorghum grain before harvesting and after drying before storage. Helping warehouse managers and grain buyers to utilize moisture meters and other crop conditioning equipment would pay measurable and lasting dividends. This will be expected to translate into higher farm gate prices, lower product losses during storage and improve sales revenue for traders and grain storage centres.

Use of different improved storage structures

Galvanized metal silos for grain storage: Depending on the extent of production, metal silos of different capacities can be used in order to store grains under hermetic condition. The technology has proven to be effective in protecting the harvested grains from attack from storage insects but also rodents and moulds. Though the initial cost could be high, silo can serve with proper handling, for up to 15 years and it would be profitable in the long run. With such types of storage structures, farmers are being forced to sell their grains immediately after harvest. Moreover, the quality of the grain will be better to fetch premium price than those using conventional storage structures.

Use of hermetic bag: There are many designs of hermetic bags being promoted for use in sub-Saharan Africa. Hermetic bag technology uses plastic bags to achieve hermetic storage of grans and other seeds. Threshed grain dried to an appropriate moisture level and free of crop debris, is placed into 50 - 100 kg capacity high-density polyethylene bags with 78 - 80-µm thickness. The bags are composed of two high-density inner polyethylene plastic liners and a woven polypropylene bag on the outside for reinforcement. The inner bag is completely filled with grain, but with a 20 to 30 cm neck, which is tied securely. Then, this bag is placed inside a second bag the neck - which is ultimately = tied securely. Finally, these two bags are placed inside a third woven and strong polypropylene bag used. With the third bag tied securely, the hermetic can be handled without bursting. Some of the common makes of hermetic bags include Purdue Improved Crop Storage (PICS), SuperSeed brandg made by GrainPro, A to Z , ZeroFly, etc. The design of these bags may differ slightly.

High Density Polyethylene Containers (Drums and Jerry Cans): The most common locally available containers include drums and recycled 20-litre capacity vegetable oil containers that are quite popular in villages throughout Africa. If closed properly and sealed, they can be used to store a small volume of seeds with the almost required hermetic condition.

3.3.5.4. Follow-up action plan

The following points can be considered as a follow-up steps or actions to reduce postharvest losses of studied grains in particular and crops in general.

Formulation of strong postharvest Policy

For the successful implementation of postharvest interventions, there should be a strong policy to backstop and sustain efforts and scale them up. Formulation of postharvest strategy alone cannot bring meaningful result unless there is organizational setup to undertake all the interventions with all the necessary packages.

Awareness creation to all actors along the supply chain

Increasing the awareness of actors along the food supply chain on different postharvest management issues deserves a prime attention. This will involve training of producers on proper field management, harvesting at the right maturity in accordance with the nature of the crop variety, field storage, drying transportation, threshing/winnowing, and storage. Using the right equipment or facilities for a particular postharvest operation will keep the safety and quality of the produce better. Simple tarpaulin or canvas use during threshing and drying could avoid losses due to spilling, contamination with dirt, and animal waste. Similarly, collectors, wholesalers and retailers need to be sensitized on the importance of proper storage, transportation, cleaning and proper use of storage pesticides in order to meet national and international standards.

In general, this approach is used in order to build the capacity of supply chain actors in respect of reducing food losses and thereby maximizing their economic benefits, ensuring food and nutrition security. The awareness creation should, however, be differently tailored to various target groups including small commercial farmers, wholesalers, retailers and small millers.

Placement of Postharvest management incubation Centers

Establishment of incubation centres that are equipped with recommended postharvest facilities is an immediate need to make sure that actors in the postharvest chain vividly observe and recognize appropriate handling systems. This may include

Grain driers: Grain drying facilities are important means of making sure that grains are harvested on time and dried to the required level before they can be stored. They can be solar powered and operated at cooperative level (e.g. solar tunnel drier). Farmers can also get this kind of service from service providers who are subsidized for installing commercial types of solar driers. Motorized grain driers could be introduced to areas where farmers are organized into primary cooperatives and unions. The cost-benefit analysis, however, requires proper study in respect of the economics of scale at which the construction and use of such driers would be feasible.

Moisture testing service: Service providers may help individual farmers in checking the moisture content of their grains before storage and charge them a reasonable fee. Primary cooperatives does have the capacity to purchase moisture-testing equipment and provide services to members and non-members on payment basis.

Improved storage at community level

Warehouse ticketing system can be used as a strategy to establish storage warehouses for farmers. In Ethiopia, there is an existing tradition of keeping goods in a rental warehouse where users pay an agreed amount of monthly service charges. If warehouses are constructed in different parts of the country, they will reduce losses associated and poor handling of grains at household level. Therefore, this system can be scaled up by establishing communal storage rooms where farmers could be charged a reasonable service charge for their crops.

Mechanized harvesting and threshing services

The absence of mechanized harvesters for sorghum in many parts of Ethiopia has increased the demand for labour needed for pre-harvest and harvest operations of sorghum and other crops especially in areas where sesame is produced. The Ethiopian Agricultural Transformation Agency has started providing service in this regard particularly in Alamata area of Tigray. Therefore, service providers can get involved in purchasing the machinery and providing service of harvesting and threshing sorghum for a reasonable service charge. For the time being, governmental and non-governmental organization should promote the use of such machinery in cereal producing areas such as Gedeb Hassasa and Debre Elias.

Proper value chain development

Value chain development: Most of the sorghum produced is consumed locally and a little amount is left for the market. With proper value chain development, the crop can be commercialized to generate more income to producers and other actors along the chain.

In order to enhance food quality along the supply chain, it is important to take collective action in grain sorting, cleaning, drying and storage. Putting in place practical interventions for reducing both quality and quantity losses requires partnerships and collaboration. For example, to make storage effective and viable, storage period and location of stores has to be coordinated.

Promote Agro-processing and value addition

There is hardly any agro-processing in sorghum except the one used for making injera and local beer. However, studies and experience in many Asian countries such as India show that sorghum can be used for many industrial and household value added product development purposes. To date, growers are selling their grains without any processing and value addition. It is a pity that there are still places where household food processing involves the use of the traditional stone mill in indicated in Figure 21 which is less efficient and back breaking.

Figure 21. Many people still use the traditional stone mill to process their grains before consumption locally called Wofcho

3.4. Postharvest loss assessment of haricot bean

3.4.1. Status and importance of Haricot beans in Ethiopia

Haricot bean is grown in different woredas of Ethiopia mainly as a cash crop. It is also produced as a supplement of staple food in Southern and Eastern parts of the country and as a crop to enhance soil fertility through fixing atmospheric nitrogen. This study covered Tach Gaint, Adami Tulu Gido Kombolcha and Lok Ababya in Amhara, Oromia and SNNP regional states respectively.

There are several varieties of Haricot beans in use in the country including white, mixed, red, and other colour types. The wide range of growth habits among varieties enable the crop to be grown in many agro-ecology conditions (Kristin et al., 1997). Also, the crop is preferred by farmers due to its early maturity nature and its moderate degree of drought tolerance, which makes it an immediate source of income and a risk aversion crop in drought-prone lowland areas of the country (Fikru, 2007; MoA, 2010). However due to limitations in use of recommended agronomic practices average annual productivity of Haricot bean is low (1.5 tons/ha) (CSA, 2015).

According to Ethiopian Commodity Exchange Market (ECX, 2016), haricot bean production during the main season in 2005/06, was 0.24 million tons. Between 2004 and 2006, the lion's share of haricot bean in the country originated mainly from Oromia (65%) followed by SNNP (22%) and Amhara (11%) regions. Generally, the crop is a source of income for the farmers, hard currency for the country and employment opportunities for many along the supply chain (MoA, 2003). In order to tap and sustain all these benefits, so far various efforts have been made to improve productivity and production. However, there is a limitation of information on issues associated with postharvest handling practices and losses of haricot bean. Therefore, the aim of this section is to present postharvest handling practices and losses of the crop under Ethiopian context.

Pulses contribute to smallholder income, as a higher-value crop than cereals, and to diet, as a cost-effective source of protein. According to CSA (2015), out of cultivated land in 2014/2015 main cropping season, total production of haricot bean from private peasant holdings accounted for 87.61, 9.88 and 2.81% of the total volume of cereals, pulses and oil seeds respectively. Haricot bean has a high nutritional value being rich in calcium, phosphorus and iron. Therefore, the crop is considered as a key crop for improving food security. Moreover, it has been mainly grown as an exportable agricultural commodity for the last 40 years.

There are two main types of haricot beans; red and white. Smallholder farmers typically grow the red bean for household consumption and market, while the white one is produced almost exclusively for the export market. As depicted in Table 42, the national haricot bean production increased approximately twofold between 2005 and 2012/13, from 138 thousand tons to 413 thousand tons and its share of total pulse production grew from 11 percent in 2005 to 16.3 percent in 2012 (CSA, 2012). Out of total volume of pulses produced (9.89%) in 2014/2015, Faba beans shared 31.34% followed by haricot beans (white and red seed types) (19.21%). The driving force behind the increasing share of exports and decreasing share of local consumption may be the lucrative international prices of haricot beans in recent years (2013 and 2014). In addition, Ethiopia can expand its foreign market presence through increased production and supply of the crop to international destinations. Attractive price for haricot beans in international markets increased in total value of exported haricot bean from 19 million USD in 2005 to 95.3 million USD in 2012, exhibiting a growth of more than threefold (ERCA, 2013). Haricot bean exports accounted for about 41 percent of pulse production and exports from 2005 to 2012. The main destinations were Yemen, UK, UAE, Pakistan, India, Belgium, South Africa, Kenya, the Netherlands, Italy and Sudan. However, in recent years as indicated in table 36, the total volume of production for white haricot bean is declining due to waning in international market prices, which negatively influenced the volume of production in the country.

According to this study that wasconducted in three woredas, the average of haricot bean yield varies from 1.13 (Lok Abaya) to 1.6 (Adami Tulu Gido Kombolcha) tons/ha which is close to the national average. In all the woredas, the major portion of production goes to wholesalers and farmers cooperatives through different channels to the export market. About 95% of the haricot bean (white) in Adami Tulu Gido Kombolcha woreda is cultivated for the market as a cash crop. Red seeded type such as *"Roba"* and *"Nasir"* varieties are often used for home consumption. The same is true in Lok Abaya woreda. However, a major portion of the beans produced in Tach Gaint is mainly used for local consumption in rural and urban areas.

Table 42. National and woreda level data on cultivated land, total production, consumption, marketing of haricot Bean

National Sorghum			
Annual production (tons/yr) (average of 8 years 2003/04-2013/14)	**Cultivated area (ha) (average of 8 years 2003/04-2013/14)**	**Average yield (tons/ha) (average of 8 years 2003/04-2013/14)**	**Remark**
2,906,663.8	251,871.7	1.14	Average values of last 10 years **2003/04** to 2013/14 (CSA Abstracts **2003/04**-2013/14)

Average annual growth for the last 8 years (%)									
2004/05	**2005/06**	**2006/07**	**2008/09**	**2009/10**	**20010/11**	**2011/12**	**2012/13**	**2013/14**	Calculated based upon CSA abstract from 2004 to 2014
-52.7*	37.8	7.8	26.8	9.1	DNA**	6.4	16.2	-79.0*	

Average cost of production (USD/Ton)	
280.1	Considering average cost of production of three studied woredas in 2015

Percentage for consumption, % PHL and % marketed in household level			
Percent consumed	**Average PHL during storage of grain**	**Percent Marketed= Total -%PHL-% consumed**	Data calculated from average values of three woredas report of Tach Gaint, ATGK, Lok Ababay in 2015 (Haricot bean grain
34	8.3	57.7	

Value of Marketed product # 1 Raw bean (USD/Year)	
4,105,299.7	This value is calculated as total production *Percent Marketed*price of one ton of maize grain (280.1 USD).

Number and sex of Producers			
Male	**Female**	**Total**	Total number of producers of the three woredas in the study area
52,006	8,565	60,571	

Levels of trading and processing operations				
	Small	**Medium**	**Large**	
Level Whole sale operation	-	*	-	
Level of retail operation	-	-	*	
Level of processing operations *	**NA**	-	-	

*Huge increase and decrease in annual growth is highly associated with the fluctuation of market price, which has a significant effect on the interest of farmers to cultivate the crop in a subsequent season. , **DNA = Data Not Available

3.4.2. Past and on-going interventions in Haricot bean loss reduction

Haricot bean postharvest losses can happen at different supply chain of the crop starting from harvesting to final consumption. Several interventions are recommended by MoARD and practised by farmers as traditional activities to minimize losses. Right harvesting stage is one of the many interventions to reduce losses by avoiding damage due to untimely rain and by minimizing field shattering of over dried pods. Farmers determine maturity by looking at the changes in the colour of leaves, stalk and pods. Traditionally farmers in Tach Gaint decide the right stage of harvest maturity when “the *crop color looks like the belly of a donkey*”. Because this stage allows them to easily uproot- the crop with reduced shattering loss. As a further loss mitigation strategy of shattering, uprooting is commonly done either early in the morning (before 9 am) or late afternoon (after 4 pm). To avoid decay and mould damage further drying is done for few days on the farm or after transported to the threshing field (3-8 days) based -on the weather condition and moisture content of pods.

Field stacking/piling is also done early in the morning or late afternoon, but transportation is done using a donkey, donkey-drawn carts or human labour by wrapping the whole crop with polypropylene sheet or chattels’ hide on anytime on the day. These days, few farmers thresh their crop on polyethylene sheets to minimize both qualitative and quantitative losses. However, the majority of them - still use the traditional threshing floor, which results in qualitative and quantitative losses. Except for Lok Ababaya, haricot is not stored for more than a month due to immediate market demand for the grain after harvesting. Since it is an exportable grain, it has a seasonal price and market demand only for short period of time by exporters. Furthermore, due to high risk of storage pests, farmers commonly do not keep (Mainly in Adami Tulu Gido Kombolcha woreda) the grain for more than a month. However, farmers in Lok Ababya use Malathion 5% dust to control damages of weevils and to store the beans up to six months. So far no data is available on the type and extent of postharvest technologies or improved practices introduced and used in relation to this crop. However, recently a hermetic bag (Super grain bag) has been introduced and is familiarized in Lok Abaya woreda to control storage insect pests damage.

3.4.3. Policy Issues in Haricot Bean Loss Reduction

These days experience shows that Ethiopia lacks a clear postharvest related policy for agricultural products in general and Haricot beans in particular. Details of policy gaps are indicated in previous section and equally applicable for Haricot beans too.

3.4.4. Relevant Institutions and their Roles in PHL Reduction of Haricot Bean

There are various government and non-government institutions involved directly or indirectly on various Haricot bean related activities. Woreda level agricultural offices, farmer’s cooperative unions and agricultural research institutes are mainly involved in pre-harvest aspects in terms of supplying improved seeds and providing advise on agronomic practices. There are also microfinance and credit and saving cooperatives which are mainly facilitating loans to farmers for purchase of agricultural inputs mainly seeds, chemical fertilizers and pesticides. In postharvest areas, farmer cooperative unions and private grain processors are involved in the cleaning of purchased grains before supply to the central or export markets. Farmers’ cooperatives and private traders also supply storage pest’s insecticides like Actellic 2%, Malathion 5% dust and raticides to control storage pests. Good marketing conditions and systems created by private buyers at the central level, farmers’ cooperatives and commodity exchange market (ECX) are directly or indirectly involved in reducing loss through creating better market price and logistics. The role of certified local buyers (licensed by regional agricultural bureaus) in terms of purchasing and supplying of better quality gains to the central market is an exemplary approach initiated and implemented to minimize losses. Agricultural research institutes and universities also doing research (breeding, agronomy, pest control) to enhance the productivity of the crop, but so far limited or no research activities are reported on postharvest handling and value addition aspects of the grain. Institutions involved in providing support during pre-harvest, postharvest and marketing activities in the three woredas are summarized and indicated in Annex Table 17.

3.4.5. Overview of Haricot Bean Supply Chains

Haricot bean in selected woredas is mainly cultivated as a cash crop to earn money and for home consumption. In the supply chain, small-scale farmers are playing the pivotal role in terms of production of the beans. The estimated total volume of product produced in the three woredas is 25,401.32 tons/year (Table 43). This volume was produced by 60,571 smallholder farmers.

Haricot bean is entirely produced by small-scale farmers. In the studied woredas, there is no state or private owned commercial farms involved in production aspect. As indicated above, it is the main income generating source for farmers. As one of the agricultural activity, it also provides employment opportunities to farmers, traders, processors and exporters in the supply chain. Generally, there are different actors involved in the marketing of the beans destined for local or international markets. Details of the supply chain with relevant actors involved in each phase of the value chain are indicated in Figure 22.

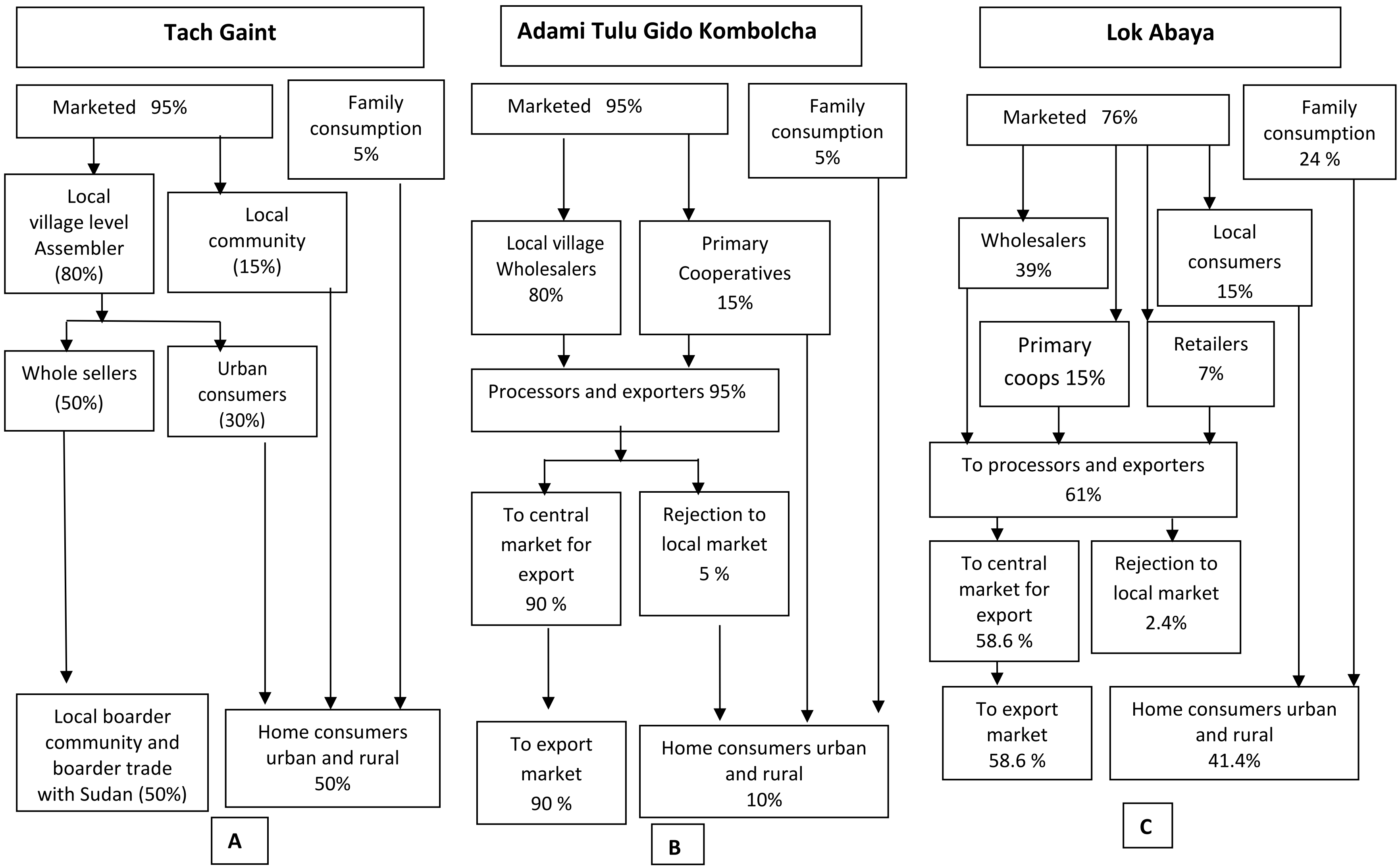


Figure 22. Supply chain of Haricot bean in Tach Gaint (A), Adami Tulu Gido Kombolcha (B) and Lok Abaya (C) woredas

Table 43. Food Supply Chains in the Subsector for Tach Gaint, Adami Tulu Gido Kombolcha and Lok Abaya Woredas

FSC #	Geographical area of production (Woreda)	Final product	Volume of final product (tons/year)	Number, age & sex of smallholder producers	Market of final product, location, buyers	Project support
1	Tach Gaint	Haricot bean	7356.8	F= 423 M= 13693	Tach Gaint for local markets	NA
2	Adami Tulu Gido Kombolcha	Haricot bean	14062.4	F= 6845 M= 20137	Raw bean to Central market for export	NA
3	Lok Abaya	Haricot bean	3,982.12	F= 1297 M= 18176	Raw bean to Central market for export	NA

As indicated in Table 44, among the studied woredas, the economic importance of the crop in Adami Tulu Gido Kombolcha and Lok Abaya woredas is high as compared to Tach Gaint. Out of the total production from Adami Tulu Gido Kombolcha and Tach Gaint woredas almost more than 95% is supplied to the central and local markets to generate money for the purchase of agricultural inputs and family use. As a cash crop in all studied woredas, the contribution of haricot bean for household or national food consumption and nutrition is low. However, still significant portion out of the total production is used for household and local consumption. This implies that the nutritional contribution of the crop is significant since it is a good source of protein and mineral elements.

Table 44. Importance of Food Supply Chains at National Level

FSC of Selected Woreda	Economic Importance	Generation of foreign exchange	Contribution to national food consumption	Contribution to national nutrition	Environme-ntal impact	Total Score
Tach Gaint	3*	1	1	1	1	**5**
Adami Tulu Gido Gombolcha	3	3	1	1	1	**8**
Lok Abaya	3	2	1	1	1	**8**

** 1= Low, 2 = Medium, 3= High*

Haricot bean is extremely important especially for farmers in Adami Tulu and Gido Komobolcha woreda in terms of employment creation, income generation and consumption purpose (Table 45). This is mainly associated with moisture prone characteristics of the woreda, which forces farmers to produce early maturing and drought tolerant crops like haricot bean as a major crop. However, the Haricot bean is not a major crop in Tach Gaint and Lok Abaya woredas. Farmers produce the crop for cash and they sell it at local and central markets and part of it is used for consumption.

Table 45. Importance of Haricot bean Supply Chains by Actors

FSC # of Selected Woreda	%age of produce by smallholders	Income generation	Involvement of the poor	Employment Provision	TOTAL SCORE
Tach Gaint	3*	2	3	3	**17**
Adami Tulu Gido Kombolcha	3	3	3	3	**20**
Lok Abaya	3	2	3	3	**18**

** 1= Low, 2 = Medium, 3= High*

Major postharvest activities and their role in terms of enhancing or minimizing losses are indicated in Table 46. In each step of postharvest activities, there are losses, which can be considered as Critical Loss Points (CLPs), or Low Loss Point (LLPs) based upon the extent of losses they incur. Based on characteristics of the crop harvesting, field drying/stacking as well as storage (except Tach Gaint) are considered as CLPs due to their relatively high percentage of quantitative and/or qualitative losses.

Table 46. Preliminary screening of food losses in the selected supply chain –Haricot bean*

FSC # Tach Gaint							
Steps in FSC	**Expected Loss Points**						**Comments and Remarks**
	Quantitative CLP / LLP			**Qualitative CLP / LLP**			
	TG	**ATGK**	**LA**	**TG**	**ATGK**	**LA**	
Harvesting/ Uprooting	CLP	CLP	CLP	LLP	LLP	LLP	High shattering of pods for quantitative loss mainly during dry and sunny conditions
Field drying /Stacking	CLP	CLP	CLP	LLP	LLP	LLP	High shattering of pods
Transportation to threshing field	LLP	LLP	LLP	LLP	LLP	LLP	Since this is done with a maximum care, it is considered as LLP
Threshing	LLP	LLP	LLP	CLP	CLP	CLP	Grains are mixed with soil, dirt and cattle's waste during threshing, breakage of grain when beaten by stick
Storage	CLP	CLP	CLP	CLP	CLP	CLP	Both quantitative and qualitative loses due to storage pests and adverse environment conditions
Marketing	LLP	LLP	LLP	LLP	LLP	LLP	Handling is done with care
TG: Tach Gaint, ATGK: Adami Tulu Gido Kombolcha, LA: Lok Abaya							

**This table is prepared from available literature information.*

3.4.6. Major supply chain of haricot bean- Situation analysis

Description of the major supply chain

In supply chain of Haricot bean, different actors are involved in different stages of different extent. In the studied Woredas, haricot bean has two supply chains; part of the total production volume goes to international market for export and part of it is used for consumption. In the two woredas except for Tach Gaint, the crop is mainly produced as a cash crop to be supplied to the central market. However, part of the produce in Tach Gaint is mainly used for consumption purpose at local villages and in nearby towns.

This is mainly because of two reasons: (i) farmers in Tach Gaint use seeds of local variety which are adapted to their local agro ecology condition but might have less preferred in central export market for export, (ii) Tach Gaint is far from the central market (more than 900 Km) and local assemblers and wholesalers have less interest because of high transportation cost and less profit margin. Details of the overall supply chain representing all woredas are indicated in Figure 23.

Harvesting is mainly done by uprooting the entire crop and proper harvesting varies among the woredas. This will be followed by field stacking for further drying purpose before transporting to a threshing field. Threshing is done using animals on the same day or after few days depending on moisture content of the crop or schedule of farmers. After threshing, particularly in case of Adami Tulu Gido Kombolcha, the grain is immediately sold within the same or few days after threshing. The same is true in Lok Abaya for the marketable portion but farmers commonly keep a small portion(approximately 25% of net harvest) of their harvest for few months (3-4 months) for home consumption or local sale and seed purpose.

Local licensed and certified primary assemblers in each woreda play a pivotal role in assembling the grains commodity from farmers' village and supplying it to secondary assemblers or wholesalers based at the woreda or nearby big towns. Primary markets for farmers are rural spot markets where most of the smallholder farmers sell their produce to assemblers and rural consumers. Agriculture offices at the district or woreda level help to control and monitor certified buyers to ensure that adulteration of beans is not done by unscrupulous traders. This helps to ensure the supply of better quality beans to the central market. Secondary assemblers (known as wholesalers) are those with a relatively better financial capacity to buy a large volume of beans and have also better storage facilities including small warehouses of 5000-10,000kg capacity. Buyers in this category include private traders and primary cooperatives where primary assemblers or farmers directly - sell their grains. At this stage, there is no value addition process to improve the quality of beans before they supply to tertiary level traders.

Farmers' cooperative unions, private processing and exporting companies are actors involved in the tertiary level of the supply chain. Both the unions and private processors carry out some do the value addition role through cleaning and grading of beans received from wholesalers and primary cooperatives before supplying they supply to the Ethiopian Commodity Exchange Market (ECX) or the export to Export market. Haricot beans stored in ECX warehouses are categorized by quality and grade and later auctioned based on the categorized grade levels. In ECX platform, exporters who agree to buy from suppliers are expected to sign an agreement, and then the ECX transfers money from the exporter to the wholesaler's account. The exporter will then ship the beans from the ECX warehouse to their own warehouse. Such type of trading minimizes the influences of brokers and benefits farmers who get a better price.

Description of the existing marketing systems

Market places and mode of transport for haricot bean are influenced by season in the woredas where the crop is grown since it is mainly purchased for export markets. haricot bean goes through various marketing channels. The major portion is sold to certified and licensed collectors in the nearby towns without value addition or processing. Cooperatives and wholesalers supply beans either to farmers, farmer's unions or to private processors (cleaning and grading) and exporters. Part of the cleaned grains from cooperative unions of Adami Tulu Gido Kombolcha woreda are sold back to farmers as a cleaned seed for the next growing season. However, major portion of cleaned beans are shipped to ECX market for final sell and export. Despite this arrangement, the study found out that, private agro-processors directly export cleaned beans of required standard to their customers. Details of inputs used, supply chain activities and actors involved as well as marketing systems of haricot bean of three woredas are described in figure 24 and 25. The major steps in the supply chain, chain actors and forms of product at each stage are explained in Table 47.

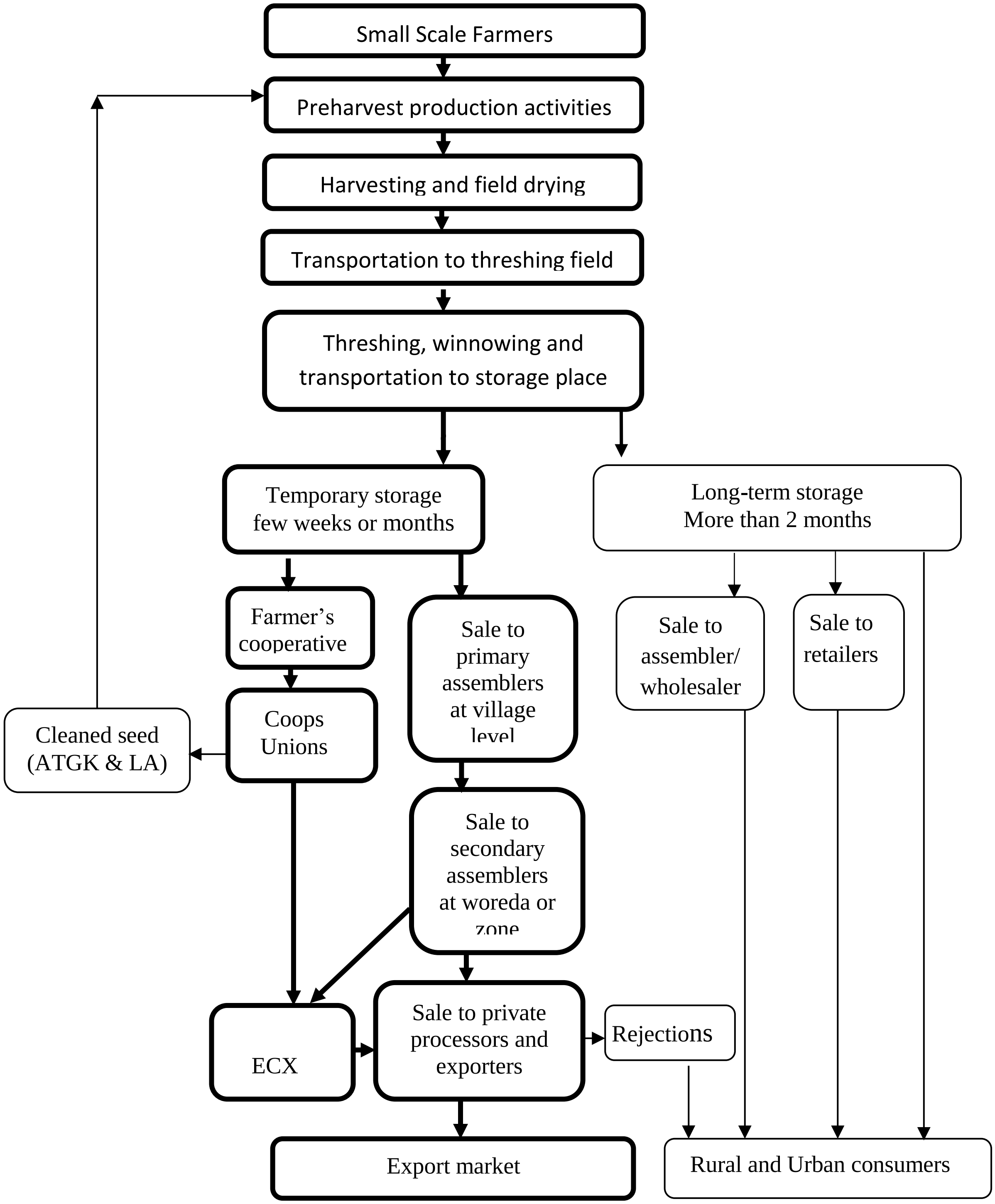


Figure 23. Supply chain of Haricot bean, part indicated in bold lines is the major supply chain (represents supply chain of three woredas)

Table 47. Steps and Products in Haricot bean Supply Chain

Process	Duration	Product out	% Weight from 100	Conversion Factor
Adami Tulu Gido Kombolcha and Lok Ababya woredas*				
Stored beans	2 -8 weeks	Raw beans	100	1
Primary assemblers	2-5 days	Raw beans	100	1
Secondary assemblers	2-3 weeks	Raw beans	100	1
Tertiary assemblers	2-4 weeks	Raw beans	100	1
ECX market (quality check and grading as it is)	1-2 weeks	Raw beans	100	1
Processors and exporters (cleaning)	2-4 weeks	Grain	90	1.11

**In the case of Tach Gaint, a major portion of production is used for household consumption and sold to local markets.*

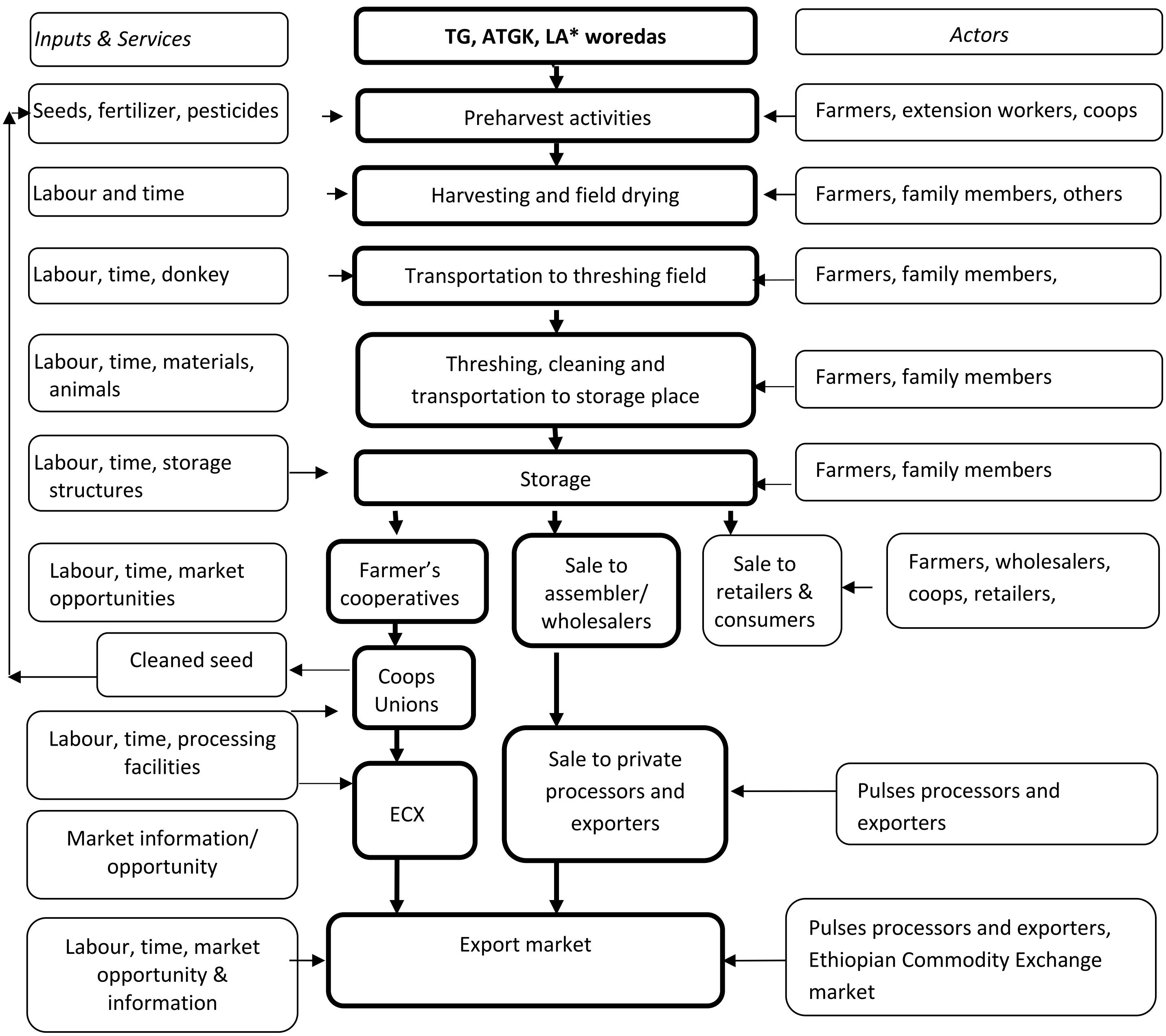
Almost all of the major national trading and warehouses for Haricot beans are located in Adama town in Oromia regional state, which is regarded as the reference market for price information, processing and export. Adama is located en-route to Djibouti port to supply the beans to international destinations.

Market price and form of product

In Ethiopia, Haricot bean is exported as a raw commodity with minimum value addition. This trend needs consideration to maintain good market price since there are more value addition and processing opportunities compared to other grains. Every year, farmers sell their Haricot beans immediately after harvest between October and January. The average prices of the three woredas during the survey year (2015) was between 24.4 and 37.2 USD per 100 kg. Recent shifts in the prices and demand for beans has led to increased risk and volatility in both prices and volumes. Due to the fluctuation of the market price in the international market, the current price is disappointingly low as compared to the previous price of 87.8 USD per 100 kg.

Market information

Access to market information in all woreda is similar. According to the study, farmers rarely get market information from radio, agricultural extension workers, farmers cooperatives, individual farmers' networks and cell phones (with very limited usage), friends and relatives. Generally, throughout the survey, farmers and traders indicated that they were unable to access regular market information. This was considered a major problem in developing marketing plans and in price discovery. Furthermore, it increases both transaction costs and resistance to risk-taking.



N.B- Bold lines showing major supply and marketing systems.

* TG: Tach Gaint, ATGK: Adami Tulu Gido Kombolcha, LA: Lok Abaya

Figure 24. Flow diagram of Haricot bean supply chain and marketing systems in the study woredas

Major market problems

The following are major market problems indicated during FGD and KII:

i. Lack of sufficient and reliable market information.
ii. High price fluctuation year after year makes farmers less confident to produce haricot bean in more efficient and sustainable manner. For instance, before three years the price was close to 88 USD/100 kg, which dropped to 24 USD/100 kg during the study year (2015)
iii. Unfair price setting by brokers/traders. This is mainly because of many intermediaries involved in the market supply chain and lack of efficient marketing system to support producers.

3.4.7.Gender Roles in PHM

Women produce between 60% and 80% of the food in most developing countries and are responsible for half of the world's food production (Hassan, 2010). The role of men and women in the postharvest management of Haricot beans shows slight variation. Among the studied woredas, the role of women is almost equivalent with that of men in Tach Gaint but is slightly more in Adami Tulu Gido Kombolcha and Lok Ababay woredas. There is no single PHM activity that is not handled by women, emphasising the role of women in PHL reduction strategies is by far crucial - compared to their role in preharvest farming practices. Details of PHM activities and scored values for men and women for each activity are indicated in Table 48.

Table 48. Detailed Description of the Food Supply Chain – Social Structures

FSC STEPS	Women			Men			Gender / social patterns Additional observations and remarks
	TG	ATGK	LA	TG	ATGK	LA	
Primary Production	2	2	2	3	3	3	Men are responsible for deciding plots for the crop and mainly involve on preparing lands and sawing, women involve in other production activities
Harvest	2	1	3	2	3	3	Women dominate harvesting but Children also participate.
Field stacking	3	1	2	2	3	3	Since stacking is a follow-up action of harvesting, women are dominant
Transportation to threshing field	3	1	3	2	3	3	Commonly this is done by women and children
Threshing & winnowing	2	2	2	3	3	3	Children highly involve with men
Transportation to storage place	3	3	3	3	3	2	Since this is s follow up step of threshing mainly done by men
Construction of storage structures	3	2	1	2	2	3	Construction of the main structure is commonly made by men and the remaining major portion will be finished by women
Storage	1	2	2	3	3	3	Men have high role to control storage grain
Transportation to market and market sale	2	2	2	3	3	2	Both involve but men involve on large volume & women on small volume to sale
Agro-processing	3	3	3	0	0	1	Women involve entirely on processing & cooking for family consumption
Storage in warehouses of coop., private processors & exporters	1	1	1	3	3	3	This is entirely men dominated at both cooperative and private processors level
Wholesale trade	1	1	1	3	3	3	Exclusively men dominate since large volume of trade by women is considered as risky business & also from culture &religion point of views
Retailing	2	3	2	2	1	2	This can be done by both with a relative dominance of men retailers in TG, and women in ATGK and LA
Seed cleaning & storage	3	3	-	3	-	3	Entirely done by women since sorting is considered as women job
Processing/ grinding, baking	3	3	3	0	0	0	This is entirely considered as women job and handled by them
Treatment/ chemical application & Pest control	1	1	1	3	3	2	Since men are close to extension service opportunities this practice is mainly handled by men
Total of the score	**35**	**31**	**31**	**37**	**36**	**39**	
% share	**72.9**	**64.6**	**64.6**	**77.1**	**75.0**	**81.3**	

***3** = High role, **2** =Medium role, **1**=Low role, **0** = no role, TG= Tach Gaint, ATGK= Adami Tulu Gido Kombolcha, LA= Lok Ababay*

3.4.8. PHL of haricot bean- Study findings

3.4.8.1. Haricot bean loss risk factors

There are many risk factors associated with PHLs of haricot bean in the supply chain. Relevant risk factors are indicated in Table 49. In addition to these risk factors, features associated with the crop and relevant postharvest practices are the major risk factors. For example, susceptibility of the pods to high shattering rate during harvesting and field drying are critical factors, which that can be managed through good PHM practices. Either as indicated in Table 47, parameters associated with each variable valued "No" or "Low" manifests high risk factors with high percentage of PHLs. As indicated in table 44a-c, estimated PHLs of Haricot bean due to various postharvest practices are 12.2, 26.2 and 37.2 % for Tach Gaint, Lok Ababya and Adami Tulu Gido Kombolcha woredas respectively.

Table 49. Food Loss Risk Factors for three Woredas (TG, ATGK, LA)

Variable	Unit	Parameter: Relation to food losses contributing to low losses	Value of variable (observed in the case study)		
			TG	ATGK	LA
Crop variety	Y/N	Resistant variety to shattering, insect, diseases	N	N	N
Good Agricultural Practices (GAP)	Y/N	Yes	N	N	N
Rainfall during production	Y/N	Optimum (Opt) range	Y	Y	Y
Production supply/ demand ratio	Ratio	< 1	>1	>1	>1
Rainfall during Postharvest phase	L/M/H	Low rainfall	L	L	L
Postharvest technology	L/M/H	High	L	L	L
Primary cooperatives / Coops union	Y/N	Yes	N	Y	Y
Processing technology	L/M/H	High	L	L	L
Good Manufacturing Practices (GMP)	Y/N	Yes	N	N	N
Packaging materials and facilities	L/M/H	High	L	L	L
Storage conditions	L/M/H	High	L	L	L
Transport duration	Hour	Low duration (<1 h)	1.5-3	1-2	1-2.5
Market information	L/M/H	High	L	L	L
Price incentive for quality	Y/N	Yes	N	N	N
Knowledge of FSC actors	L/M/H	High	L	L	L
Consumer access to food product	L/M/H	High	L	L	L

Legend: Y/N = Yes / No; L/M/H = Low / Medium / High.
Key: TG-Tach Gaint, ATGK-Adami Tulu Gido Kombolcha, and LA-Lok Ababya woredas.

3.4.8.2. Observed PHLs and Critical Loss Points (CLPs)

In the following sections, observed PHLs and identified CLPs for the supply chain of Haricot bean are discussed. Detail descriptions are included in Table 48-50.

Losses during harvesting

The maturity of haricot bean is determined by looking at the colour of leaves and pods. In all the woredas, harvesting or uprooting starts as the stalk dries out; and leaves become yellowish to grey, without completely weathering. This is considered as an optimum harvesting time and harvesting may commence if there is no rain. Harvesting is done manually (uprooting the whole plant from the field) using family labour either early in the morning (between 6:00 and 10:00 am o'clock) or in the late afternoon starting from 4:00 pm to late evening to minimize grain shattering losses.

Haricot bean loss starts at harvest, and that why this stage is considered as a Critical Loss Point (CLP) in the supply chain. Even though harvesting is commonly done during the times mentioned above, still the loss due to shattering is significant mainly in Adami Tulu Gido Kombolcha (Table 48). This might be associated with very dry and hot climate since it is located in the central rift valley region of the country. Furthermore, unlike other two woredas, farmers using improved varieties (Awash 1 and Awash Melka varieties developed for yield and export market but are not less sensitive to shattering). Harvesting loss in Lok Abaya woreda is also high (Table 49) however, unlike -the other two woredas the loss due to harvesting in Tach Gaint is unexpectedly low (Table 50). This might be due to the shattering resistance nature of the bean growing in the woreda and the experience of farmers in determining the optimum harvesting time. In all woredas, rarely, harvesting schedule and yield of the crop are affected by untimely rain during harvesting season. This condition enforces farmers to harvest the crop when the weather gets dry, which leads to the extended period of harvesting and more shattering losses on the field. However, as compared to quantitative loses, qualitative losses due to harvesting is almost negligible unless - there is a loss due to mould growth and rotting because of high moisture of untimely rain. Harvesting is mainly managed by men; women and children labours of the family. Sometimes causal labour is used (Adami Tulu Gido Kombolcha) based on the size of the farm and scarcity of labour in a family.

Field drying/ stacking associated losses

Field drying is one of the postharvest operations in haricot bean production. This operation is labour intensive and - needs great care to reduce shattering of grains. On average, field drying can take one to eight days based -on the stage of uprooting of the crop. In Adami Tulu Gido Kombolcha and Lok Ababay, the crop is uprooted when it's fully dried. But when the crop is harvested at relatively high moisture content as it is done in Tach Gaint, field drying commonly takes longer time (up to 8 days). Due to this reason, field drying is commonly done for an extended period of time till the pods reach the optimum moisture content for threshing. However, due to immediate threshing after harvest, field-drying loss in Adami Tulu woreda is low as compared to other woredas (Table 48-50) because beans are harvested when they are dry enough to be threshed immediately after harvest. Some insect damage and disease infection (qualitative loss) may occur during field drying, like damages because of termites, and mould growth due high moisture accumulation from the untimely rain.

Loss due to transportation to threshing field

After harvesting, farmers transport the uprooted crops along with the stalk using human labour or donkey. Before transportation, the crop is wrapped with a skin of cattle's, mosquito net, or polypropylene sheet to minimize seepage and shattering loss. Loss (quantitative) due to this activity in Tach Gaint, Adami Tulu Gido Kombolcha and Lok Ababay woredas are indicated in Table 48-50.

Threshing and winnowing losses

Once harvesting and field drying is done, the crop transported and threshed on threshing floor/canvas (based -on the economic status of the farmers) or in bags using either human labour or cattle's. In all three woredas, since threshing and winnowing are done traditionally still there are loses. Losses associated in this stage are high in Tach Gaint and Lok Abaya but low in Adami Tulu Gido Kombolcha. Qualitative losses also occur due to various reasons as indicated in Table 48-50.

Storage associated losses

Farmers in Tach Gaint store beans in storage structures that are - placed indoor or outdoor. *Gota* (made of mud), *Gotera* (made of wood but plastered with mud or cow dung) and "*Aqumada"* (sack made out of Goat skin) are the major Haricot bean storage structures in the woreda. Storage associated loss in this woreda is 4.5% (due to insect pests, moulds and scattering). However, according to farmers' observation and information, the problem of weevil on Haricot bean in this woreda is a recent phenomenon (in the past 2 years) and hence the loss is not as such in big magnitude as compared to the other two woredas.

The yield of Haricot bean in Adami Tulu Gido Kombolcha, is mainly transported and stored using polypropylene bags. The product is stored only for short period of time (days or couple of weeks) and immediately marketed because of the following reasons:

i. .
ii. White haricot bean is an export commodity, which is commonly purchased, processed and exported within 2-3 months after harvesting. Farmers who fail to sell their beans within this time may not get a buyer or better price, since there is no continuous processing and exporting activity.
iii. As a result of the unconducive warm climatic condition, the impact of storage insect pests is very significant (up to 14% loss as indicated in table 43b) if beans are stored for more than a month. To avoid such a loss, farmers implement immediate marketing as a prevention strategy for pests attack than store the beans.

In Loka Abaya, storage associated loss is estimated at 6.5% (Table 50-52) or more in the absence of control insect pests. Farmers in this woreda store beans up to 4 months targeting better prices and household consumption. To control bean weevils they use Malathion 5% dust powder and phostoxin (fumigant insecticide) as preventive and curative measures. According to discussions held during the study, mould growth and rotting in home stored beans due to migration or seepage of moisture is another factor in this woreda, but when compared to weevil's damage it is insignificant.
Generally, losses indicated in the above postharvest activities have a significant impact on the income of farmers since lead to both qualitative and quantitative losses. Farmers also have a high concern on losses during harvesting, field drying and storage, since these are the major CLPs, which are inducing loss of large volume of beans. There are also minor losses at cooperatives, farmers' unions and private processors levels, but the intensity of loss is not significant compared to losses in farmers' condition.

Processing
The main food product prepared from Haricot beans (other than white type) in the three woredas is "*nifro*", a boiled bean. The grains are hard to cook and therefore need a lot of firewood to boil the beans. The white variety beans can also be used for making "*shiro*", a roasted and ground powder, which is used in making a stew.

Table 50. Summary Result Matrix of Food Losses -Adami Tulu Gido Kombolcha Woreda

FSC stage/ process	Type of loss QN/ QL	% lost in this process /QN/	% of the product incurred QL in this process	% of product goes through this stage	% loss in the FSC	Cause of loss/ Reason for low loss	Reduced market value (%)	CLP / LLP	Destination of QL food loss (discard, consumption, sale)	FSC actors affected (men / women)	Impact of PHL at the FSC	Loss perception of FSC actors (men / women)	Suggested solutions
Harvesting	QN	20.8		100	20.8	High shattering loss & loss due to termites damage before harvesting		CLP	Consumed	Farmers	Income	More concern	- Breeding work to develop shattering resistant variety -Proper harvesting, -Control of termites, -Care during stacking and field drying, -transport early in the morning or late afternoon -Use of small scale threshing machine, use of canvas or plastic sheets to thresh gains
	QL		1		1		1						
Field drying/ stacking	QN	1		78.2	1	Shattering of pods, spillage loss		LLP	Consumed	Farmers	Income	Less concern	
	QL		0				0						
Transportation to threshing field	QN	0.13		77.2	0.13	Loss due to spillage loss during transportation		LLP	Consumed	Farmers	Income	Less concern	
	QL		0		0		0						
Threshing and winnowing	QN	0.2		77.07	0.2	Scattering loss and loss due to grain admixture with soil, stones, chaff, animals dung		LLP	Consumed	Farmers	Income	Less concern	
	QL		0.1		0.1		0.1						
Storage	QN	12		76.77	12	Damages due to insects, pests, domestic animals		CLP	Consumed	Farmers	Income	More concern	
	QL		2		2		2						
Transportation to market & marketing	QN/ QL	Almost nil	Almost nil	62.77									

Table 51. Summary Result Matrix of Food Losses: Lok Abaya Woreda

FSC stage/ process	Type of loss QN/ QL	%age lost in this process /QN/	% of the product incurred QL in this process	% of product goes through this stage	%age loss in the FSC	Cause of loss/ Reason for low loss	Reduced market value (%)	CLP / LLP	Destination of QL food loss(discard, consumption, sale)	FSC actors affected (men / women)	Impact of PHL at the FSC	Loss perception of FSC actors (men / women)	Suggested solutions
Harvesting	QN	5.4		100	5.4	High shattering loss of pods due to aggressive harvesting		CLP	Discard	Farmers	Income	More concern	- Breeding work to develop shattering resistant variety , -Proper harvesting , -Control of termites, -Care during stacking and field drying , -transport early in the morning or late afternoon , -Use of small scale threshing machine, use of canvas or plastic sheets to thresh gains
	QL		0		0		0						
Field drying/ stacking	QN	3		94.6	3	Shattering of pods, rotting due to untimely rain		CLP	Discard	Farmers	Income	Less concern	
	QL		0.6		0.6		0.6						
Transportation to threshing field	QN	3.6		91	3.6	Loss due to spillage loss during transportation		LLP	Discard	Farmer	Income	No concern	
	QL		0		0		0						
Threshing and winnowing	QN	5.2		87.4	5.2	Scattering loss and admix of grains with soil, stones, chaff, animals dung		LLP	Consumed	Farmers and other consumer	Income and health	More concern	
	QL		1.9		1.9		1.9						
Storage	QN	5.5		80.3	5.5	Damages due to insects pests, mold damage, scattering, domestic animals		CLP	Consumed	Farmers and other consumer	Income	More concern	
	QL		1		1		1						
Transportation to market & marketing	QN	negligible	negligible	73.8			0						
	QL	negligible	negligible				0						

Table 52. Summary Result Matrix of Food Losses: Tach Gaint Woreda

FSC stage/ process	Type of loss QN/ QL	%age lost in this process /QN/	% of the product incurred QL in this process	% of product goes through this stage	%age loss in the FSC	Cause of loss/ Reason for low loss	Reduced market value (%)	CLP / LLP	Destination of QL food loss (discard, consumption, sale)	FSC actors affected (men / women)	Impact of PHL at the FSC	Loss perception of FSC actors (men / women)	Suggested solutions
Harvesting/ Uprooting	QN	0.8	0	100	0.8	Shattering , poor harvesting		LLP	consumed	Farmers	income	less concern	- Awareness creation - Training on FSC, - Good post-harvest extension, - follow up - - Scaling up of good PH practice, - improved storage technologies, - Strong farmers' cooperatives
	QL		0		0		0						
Field drying / Stacking	QN	1.92		99.2	1.92	Shattering loss, poor handling			consumed	Farmers	income	less concern	
	QL		0				0						
Transportation to threshing field	QN	0.5		97.28	0.5	Less care during transportation		LLP	consumed	Farmers	income	less concern	
	QL		0		0		0						
Threshing & winnowing	QN	3		96.78	3	Crop is considered as less important, threshing is done by children		CLP	consumed	Farmers	income	Threshing and winnowing	
	QL		1.5		1.5		1.5						
Storage	QN	2.5		92.28	2.5	insect pests & poor storage handling practices		CLP	consumed	Farmers	income	-	
	QL		2		2		2						
Transportation to market	QN	0		87.78	<0.1	-		-	-	-	-	-	
	QL		0		<0.1		<0.1						
Marketing & processing	QN/QL	Almost nil	Almost nil	87.78		-	-	-	-	-	-	-	

3.4.8.3. Causes of losses and identified loss reduction measures
Annex Figure 1 shows the basic, underlying and immediate causes of Haricot bean loss in the postharvest chain with associated lose symptoms and type of losses. Basic causes associated with issues related to macro level in terms of the absence of supporting policies, infrastructures and economic disability of the nation and the country as a whole. Underlying causes are related to the absence of service providers and technologies, trained human power as well as economic limitation of farmers to use available services and technologies to reduce losses. The cumulative effects of the above causes will lead to immediate causes for postharvest loses of the grain in terms of physical, chemical, biological and cultural practices. Details of and other issues are indicated somewhere in the same document for other crops and equally apply to this crop.

3.4.8.4. Low Loss Points (LLPs) and Good Practices
Low loss points (LLPs) in Haricot bean supply chain among the studied woredas are not the same. For instance, the quantitative loss associated with harvesting is low in Tach Giant woreda compared to the high loss in Adami Tulu Gido Kombolcha. As indicated in Table 50, the low loss during harvesting in Tach Gaint can be due to optimum harvesting stage and type of haricot beans used. Farmers through their experience accumulated over the years have optimized the right harvesting stage before the pods start shattering. Recommended seeds moisture content for optimum harvesting commonly is below 16%. However, farmers in Tach Gain might uproot the crops when the moisture content is even above this value. That is why a long period (up to 8 days) of field drying is practised to bring down the moisture content to the optimum level. In addition to this, haricot beans cultivated in this woreda are of local varieties and which are likely to have pods that are tolerant to shattering during harvesting. In contrast to this, field loss in Adami Tulu Gido Kombolcha is low because of immediate threshing, which is done within a day after field drying and harvesting. This might be the concern of farmers who strive to save grains since they have already experienced significant loss during harvesting.

In all woredas, loss during transportation of the crop to the threshing site and from the threshing site to stores are low because this sub-activities is done with maximum care. Use of insecticides to control weevils in Lok Ababay woreda and immediate sell of the grain after threshing in case of Adami Tulu Gido Kombolcha can also be considered as a good practice to minimize losses during storage as long as there is a proper control of insect pests and good market price.

3.4.9. Haricot bean loss reduction strategy-Conclusions and recommendations

3.4.9.1. Impact of Haricot Bean Losses

Economic impact
Haricot beans loss has a significant impact on economic terms. For instance, considering the average postharvest loss of the three woredas due to various postharvest activities (25.2%), the total quantitative loss of three woredas as indicated in Table 53, is estimated at 6234.6 tons /yr. In terms of monitory value, considering the average current price in three woreda (Table 45), is estimated to be 1.6 million USD/ yr. This amount can be considered as a reduction from a farmers' income or foreign currency loss of the country.

Impact on nutrition and food security
PHL of Haricot bean not only impose economic loss but also has a significant impact on nutrition and food security of the country. Farmers mainly in Tach Gaint and Lok Ababaya woreda consume the bean as a major source of protein. Even though it is in small portion the bean is also consumed as a good snack (boiled or roasted one) food for the family in Adami Tulu Gido Kombolcha woreda. Qualitative and quantitative losses of the beans will aggravate food and nutrition insecurity of the nation.

Considering only losses in the three woredas, the estimated total loss in caloric value is 2.1 billion kcal. In addition to this amount of loss in caloric value, loss in proximate compositions as well as mineral elements is significant and has a critical impact on nutrition security of the country.

Impact on recourses

Postharvest loss can also be translated as wastage of preharvest resources like land, water, agricultural inputs, labour and other resources that were used to produce the amount lost per year. For example, considering the average productivity of 1.44 tons/ha, the amount of land wasted due to loss of 7172.1 tons of Haricot bean can be estimated as 4,131.6 ha.

Table 53. Economic, land and caloric value impact of PHL of haricot bean in three woredas

Woreda (a)	Total production (tons/yr) (b)	Estimated PHL (%) (c)	Productivity Tons/ha (d)	Total PHL from total (tons/yr)ᶲ e= (b*c)/100)	Price of One ton (USD) (f)	Economic Loss (USD /yr) (d*f)	Equivalent land loss in hectare due to PHL (e/d)	Caloric value Loss in kcal/yr**
Tach Gaint	7,356.80	7.20	1.60	531.20	244.00	129,603.27	332.00	179,001,244.00
ATGK	14,062.40	34.10	1.60	4799.50	244.00	1,171,077.30	2999.70	1,617,430,529.00
Lok Abaya	3,982.10	22.70	1.13	903.90	354.00	319,993.59	799.90	304,626,668.00
Total	**25,401.30**			**6234.60**		**1,620,674.16**	**4,131.61**	**2,101,058,441.00**
Mean	**8467.10**	**21.40**	**1.44**		**280.67**			

During the study time the exchange rate of1 USD was equivalent to 20.5 ETB (Ethiopian Birr);price of 100 kg is calculated from the average price of 12 months in 2015 when the price of Haricot bean was in the lowest as compared to previous price a few years back.**There are 337 calories in 100 grams of Haricot Bean Flour (Marquart et al., 2008)*

ᶲ This value includes only Quantitative loss

The high loss in postharvest coupled with low or fluctuating market price will result in farmers demotivation and disappointment to produce more in the subsequent seasons. This is practically observed during the study period when farmers aggressively expressed their disappointment due to the low price of the beans in recent years.

3.4.9.2. Required Inputs and Cost-Benefit Analysis of Haricot Bean Loss Reduction Measures

Loss due to harvesting is very high in haricot bean supply chain. Minimizing this loss at the initial stage of postharvest handling practices will contribute a lot to supply of the beans to the market. Harvesting loses can be reduced either through improving harvesting practices or through developing varieties which are resistant to pods splitting and grains shattering. Determining optimum harvesting time leads to low shattering loss, for instance, experience of Tach Gaint farmers can be taken as one of the strategies to reduce losses during harvesting. Harvesting of pods with relatively higher moisture content can minimize pods splitting and grains shattering but needs relatively longer field drying time. This experience can be optimized and shared with other growers in other regions to reduce shattering loss.

Study result shows that, particularly in ATGK woreda, grain is mainly produced as a cash crop for export market. Since the time of collection and export of the grain is time-dependent (not more than 3 months after harvesting), consistent price with good marketing system will play a significant role to reduce storage associated losses through the immediate sell of the beans. In addition to this, when the market price is not attractive, producers can keep the yield using a different type of improved hermetic storage methods like use of Super Grain bag, Purdue Improved Cowpea Storage (PICS) System and metal hermetic silos. These storage methods limit diffusion of oxygen and moisture from outside environment to the beans. With extended storage (more than 3 weeks) oxygen in bags is depleted through respiration process and eventually, very little or no oxygen will be available to support the survival and reproduction of storage insects. As a good mitigation strategy in loss reduction during storage, grains should be dried properly to optimum moisture content and farmers should be trained on proper drying of grains before storage. When cost-benefit analysis is calculated (Annex Table 18 and 19) with the anticipation of 95% lose reduction during storage, 18.6 USD and 10.1 USD benefit per year can be achieved using hermetic bags and galvanized metal silo respectively. With the reduced price of these storage methods and improvement of the market price of the bean more profit can be made.

3.4.9.3. Follow up Action Plans

Losses occur at different postharvest steps, but the extent of loss during harvesting; drying and storage is very high. Future action plans should consider these three main postharvest stages. National breeding programs for haricot beans should not only consider developing high yielding and disease resistant varieties but also aspire to develop better quality and high shattering resistant varieties. Appropriate improved postharvest handling practices or technologies for efficient field drying, transportation and threshing of grains should be developed and distributed to farmers. Research activities in this regard at the national level are almost null and the national research strategy should consider generating of such type of technologies. Hermetic plastic bags are cost-effective and efficient methods to reduce storage-related losses. Their timely availability and distribution need to be supported and coordinated by both public (policy) and private stakeholders.

Haricot bean is mainly produced as a cash crop for export market, which is mainly bounded by short marketing time (3-4 months after harvest). Furthermore, the price of the grain is highly volatile year after year. This significantly affects the motivation of farmers to produce more and even to give- care for harvested grains. Therefore, good marketing system related to this grain and other agricultural products is important to improve the whole supply chain. Agro-processing options also should be explored to add value to the beans and - stabilize market price by exploring their use as raw materials in agro-food processing industries. Furthermore, consistent awareness creation through training and extension programs in terms of causes, and impacts of postharvest loses as well as mitigation strategies should be provided.

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ANNEXES

ANNEX 1. TABLES

Annex Table 1. Postharvest Practices and method of calculation of losses at each Postharvest practices

Postharvest practices associated with PH losses	Estimated potential loss at this stage (100kgs)	Potential estimated at this stage in percent
1. Phase 1- Before storage practices		
1.1 Loss during harvesting	h	h/B*100
1.2 Loss during field drying	f	f/B*100
1.3 Loss during de-heading	d	d/B*100
1.4 Loss during transporting to threshing floor	t	t/B*100
1.5 Loss during temporary storage	x	x/B*100
1.6 Loss during threshing and winnowing	y	y/B*100
2. Phase 2- Losses during storage for net yield 2.1.1 Rodents 2.1.2 Insect pests 2.1.3 Mould 2.1.4 Domestic animals	a = r + i + m+n r i m n	a/A*100 r/A*100 i/A*100 m/A*100 n/A*100
Subtotal of loss due to pre-storage practices	z = (h+f+d+t+x+y)	z/B*100
Net yield obtained before storage & after winnowing	A	
Total potential yield that could be obtained if there is no loss at all stages of PH practices	B = Total losses before storage (z) + Net yield obtained before storage (A)	

Annex Table 2. Format to determine feasibility of recommended PH technology losses

Alpha-bets	Item	Value	Unit	Calculation formula	Profit of solution for recommended technology or method
a	Product quantity		tons/year		
b	Product value		$/ton		
c	Loss rate		%		
d	Anticipated loss reduction		%		
e	Cost of intervention		$		
f	Depreciation		years		
g	Yearly costs of investment		$/year	e / f	
h	Yearly costs of operation		$/year		
i	Total yearly costs of solution		$/year	g + h	
j	Client costs per ton product		$/ton	i / a	
k	Food loss		tons/year	cx a	
l	Economic loss		$/year	kxb	
m	Loss reduction		tons/year	kxd	
n	Loss reduction savings		$/year	mxb	
o	Total Client costs		$/year	i = axj	
p	Profitability of solution		$/year	n - o	

Annex Table 3. Cost-benefit analysis for Super Grain bag and PICS to store Maize

Alpha b-ates	Item	Unit	Calculation formula	Profit of solution for Super grain bag and PICS	Remark	Remarks how it is calculated
a	Product quantity	tons/year		4.32	average value of three woredas for a farmer per hectare	Out of 4.72 tons (average of 3 woredas) only 91.5 % goes to storage (average) i.e. Total production minus non storage related losses
b	Product value	USD/ton		196.8	Average price of three woredas	
c	Loss rate	%		0.135	Average storage related loss of three woredas (13.5%)	
d	Anticipated loss reduction	%		0.95	By 95 % of storage associated loses	Using hermetic bags during storage at least 80% of losses can be reduced
e	Cost of intervention	USD		106.2	Average price of a bag of 1.71 USD/bag *65 bags for 4.32 ton of grain.	To store 4.32 ton of maize in hermetic bags 4.72 ton *1 ton/1000kg = 4320 * 70 kg /bag = 62 bags . Price of one bag = 35 birr/ 20.5 USD
f	Depreciation	years		5	5 years estimated service life of hermetic bags with care	
g	Yearly costs of investment	USD/year	e **/** f	21.24		
h	Yearly costs of operation	USD/year		0	no yearly cost of operation	
i	Total yearly costs of solution	USD/year	g **+** h	21.24		
j	Client costs per ton product	USD/ton	i **/** a	4.92		
k	Food loss	tons/year	c x a	0.58	per hectare per a farmer	
l	Economic loss	USD/year	k x b	114.74		
m	Loss reduction	tons/year	k **x** d	0.55		
n	Loss reduction savings	USD/year	m x b	109.0		
o	Total Client costs	USD/year	i = a x j	91.7		
p	Profitability of solution	USD/year	n **-** o	17.3	By storing grains in hermetic bags storage losses can be reduced by 80% and a profit of 17.3 USD per year can be obtained	

Annex Table 4. Cost-benefit analysis for metal silo to store Maize

Alpha -bet	Item	Unit	formula	Profit of solution for metal silo	Remark	Remarks how it is calculated
a	Product quantity	tons/year		4.32	Average value of three woredas for a farmer production per hectare and year	Out of 4.72 tons (average of 3 woredas) only 91.5 % goes to storage (average) i.e. Total production minus non-storage related losses
b	Product value	USD/ton		341.5	Average price of three woredas	
c	Loss rate	%		0.135	Average storage related loss of three woredas (13.5%)	
d	Anticipated loss reduction	%		0.95	By 95 % of storage associated loses	Using hermetic bags during storage at least 80% of losses can be reduced
e	Cost of intervention	USD		878.05	Average price of a metal silo is 4500 ETB with 20.5 USD exchange rate for 1000 kg capacity	
f	Depreciation	years		15	15 years service	
g	Yearly costs of investment	USD/year	e **/** f	58.5		
h	Yearly costs of operation	USD/year		0	Assuming that very small or no yearly operation cost	
i	Total yearly costs of solution	USD/year	g **+** h	58.5		
j	Client costs per ton product	USD/ton	i **/** a	13.55		
k	Food loss	tons/year	c x a	0.58	Per hectare per a farmer	
l	Economic loss	USD/year	k x b	199.11		
m	Loss reduction	tons/year	k **x**d	0.55		
n	Loss reduction savings	USD/year	m x b	189.2		
o	Total Client costs	USD/year	i = a x j	252.8		
p	Profitability of solution	USD/year	n **-** o	-63.7	By storing grains in hermetic bags storage losses can be reduced by 95% & a profit of negative -63.7 USD per year can be lost & hence this is not a recommended method	

Annex Table 5. Supporting institutions and their respective roles in production, marketing and postharvest of wheat in Debre Elias Woreda

#	Name of supporting institution	Activities		
		Production	Marketing	Postharvest
1	Amhara Credit and Saving institute (ACSI)	Loan for purchase of inputs for other crops	NA	NA
2	Agriculture Transformation Agency (ATA)	Technical advisory service	NA	Multi crop thresher
3	Food and Agriculture Organization (FAO)	NA	NA	Training to 200 farmers
4	Melkassa Agricultural Research Center (MARC)	NA	NA	Training for 4 Artisans on metal silo construction
5	Private investors	NA	NA	Service provision with combine harvester
6	Debre Zeit Agricultural Research Center (DZARC)	Variety trial station at Debre Elias	NA	NA
7	Trade and Industry office, Marketing information forecasting division	NA	Market information	NA
8	Gozamen Union	Input supply	Purchase of grains	NA

Annex Table 6. Supporting institutions and their respective roles in production, marketing and post-harvest of wheat, in Ofla Woreda

#	Name of supporting institution	Activities		
		Production	Marketing	Postharvest
1	Dedebit Microfinance	Loan for purchase of inputs for other crops	NA	NA
2	Effort (Relief Society of Tigray)	Loan for purchase of inputs for other crops	NA	NA
3	Food and Agriculture Organization (FAO)	NA	NA	Training to farmers
4	Melkassa Agricultural Research Center (MARC)	NA	NA	Training for 4 artisans
9	ATA	Materials (e.g. Plow)	Yes	NA
10	Holeta Agricultural Research Center (HARC)	Research	NA	Training for 50 farmers and 5 DAs
11	CASCAPE	Technical support	NA	NA
12	Cooperatives (every Kebele)	Supply of inputs	Grain collection	NA
13	Alamata Agriculture Research Centre	Research on farmers plot	NA	NA

Annex Table 7. Supporting institutions and their respective roles in production, marketing and post-harvest of wheat, in Gedeb Hasasa Woreda

#	Name of supporting institution	Activities		
		Production	Marketing	Postharvest
1	FAO	NA	NA	Training for DA's, Farmers artisans to construct metal silos
2	Woreda agricultural offices with FTCs	Extension service	Market advise	Minimal PH work
3	Woreda cooperative promotion agency	Supply agricultural inputs	Facilitate marketing	NA
4	Oromia Credit and Saving S.C	Facilitate credit	NA	NA
5	Commercial bank of Ethiopia	Facilitate credit	NA	NA

Annex Table 8. Supporting institutions and their respective roles in production, marketing and post-harvest of wheat, in Soro Woreda

#	Name of financial institution	Activities		
		Production	**Marketing**	**PHM**
1	FAO	NA	NA	Training for DA's and farmers
2	Omo Microfinance	Loan for purchase of inputs for other crops	NA	NA
3	Wisdom Fund	Loan for purchase of inputs for other crops	NA	NA
4	Woreda Agricultural Office	Extension services, supply inputs, other supports	Market advise	Minimal PH work
5	Cooperatives/union (Sodama farmers' cooperative union)	Facilitate credit services, inputs supply	Facilitate purchase of farmers product with better price	Service to farmers nil, but the union make primary cleaning before supply to central market

Annex Table 9. Cost-benefit analysis for Super Grain and PICS bags for wheat storage

Alphabet	Item	Unit	Calculation formula	Profit of solution	Remark	Remarks how it is calculated
a	Product quantity	tons/year		3.32	Average value of three woredas for a farmer per hectare	Out of 3.8 tons (average of 3 woredas) only 87.4 % goes to storage i.e. Total production minus non storage related losses
b	Product value	$/ton		376.28	Average price of three woredas	
c	Loss rate	%		0.066	Average storage related loss of three woredas (6.6%)	
d	Anticipated loss reduction	%		0.95	by 95 % of storage associated loses can be reduced using hermetic bags	
e	Cost of intervention	$		80.37	Average price of a bag of 1.71 $/bag *47 bags for 3.32 ton of grain.	To store 3.32 ton of maize in hermetic bags 3.32 ton *1 ton/1000kg = 332 kg * 70 kg /bag = 47 bags
f	Depreciation	years		5	5 years estimated service life	
g	Yearly costs of investment	$/year	e **/** f	16.074		
h	Yearly costs of operation	$/year		0	no yearly cost of operation	
i	Total yearly costs of solution	$/year	g **+** h	16.074		
j	Client costs per ton product	$/ton	i **/** a	4.84		
k	Food loss	tons/year	c x a	0.22	per hectare per a farmer	
l	Economic loss	$/year	k x b	82.48		
m	Loss reduction	tons/year	k **x**d	0.21		
n	Loss reduction savings	$/year	m x b	78.4		
o	Total Client costs	$/year	i = a x j	53.4		
p	Profitability of solution	$/year	n **-** o	25.0	By storing grains in hermetic bags storage losses can be reduced by 80% and a profit of 25.0 USD per year can be obtained. Another benefit is the availability of food for the household hence improved food security.	

Annex Table 10. Cost-benefit analysis for metal silo to store Wheat

Alphabet	Item	Unit	Calculation formula	Profit of solution for Super grain bag and PICS	Remark	Remarks how it is calculated
a	Product quantity	tons/year		3.32	average value of three woredas for a farmer per year production/ha	out of 3.8 tons (average of 3 woredas) only 87.4 % goes to storage (average of three woredas) i.e. Total production minus non storage related losses
b	Product value	$/ton		376.3	Average price of three woredas	
c	Loss rate	%		0.066	Average storage related loss of three woredas (6.6%) from Table 24a-Table 24d	
d	Anticipated loss reduction	%		0.95	Using metal silo during storage at least 95% of losses can be reduced	
e	Cost of intervention	$		657	Average price of a metal silo is 4500 ETB with 20.5 USD exchange rate for 1000 kg capacity is 219.5 USD	To store 3.32 ton of maize in hermetic bags 3ton *1 ton/1000kg = Price of one bag =4500 birr/ 20.5 USD =219 USD
f	Depreciation	years		15	15 years service	
g	Yearly costs of investment	$/year	e / f	43.8		
h	Yearly costs of operation	$/year		0	assuming that very small or no yearly operation cost	
i	Total yearly costs of solution.	$/year	g + h	43.8		
j	Client costs/ton product	$/ton	i / a	13.19		
k	Food loss	ton/yr	c x a	0.22	per hectare per a farmer	
l	Economic loss	$/year	k x b	82.48		
m	Loss reduction	ton/yr	k x d	0.21		
n	Loss reduction savings	$/year	m x b	78.4		
o	Total Client costs	$/year	i = a x j	145.5		
p	Profitability of solution	$/year	n - o	-67.1	By storing grains in hermetic bags storage losses can be reduced by 95% and a profit of -67.1 USD per year can be obtained. The high price of the raw materials for making metal silos is contributing to this situation.	

Annex Table 11. Supporting institutions and their respective roles in production, marketing and post-harvest of sorghum, in Alamata Woreda

#	Name of supporting institution	Activities		
		Production	**Marketing**	**Postharvest**
1	Dedebit Microfinance	Loan for purchase of inputs for other crops	NA	NA
2	Effort (Relief Society of Tigray)	Loan for purchase of inputs for other crops	NA	NA
3	Food and Agriculture Organization (FAO)	NA	NA	Training to farmers, DAs & Artisans
4	Melkassa Agricultural Research Center (MARC)	NA	NA	Multiplication of metal Silos and Training
5	ATA(Agricultural Transformation Agency)	Soil fertility	Value chain	NA
6	Alamata Agriculture Research Center	Developing adaptable varieties	NA	NA

Annex Table 12. Supporting institutions and their respective roles in production, marketing and postharvest of Sorghum, in West Armacho Woreda

#	Name of supporting institution	Activities		
		Production	Marketing	Postharvest
1	FAO	NA	NA	Training for artisans
2	ACSI (Amhara Credit and Saving Institute)	Loan	NA	-
3	ATA(Agricultural Transformation Agency)	Soil fertility	Value chain	NA
4	SBA		NA	NA

Annex Table 13. Supporting institutions and their respective roles in production, marketing and post-harvest of sorghum, in Derashe Woreda

#	Name of supporting institution	Activities		
		Production	**Marketing**	**Postharvest**
1	FAO	NA	NA	Training for DA's, Farmers artisans to construct metal silos
2	Omo microfinance	Loan for inputs	NA	NA
3	NGO (Mercy Corps)	NA	NA	Polyethylene lining pit wall to avoid moisture migration (not accepted by farmers)
4	Woreda Agricultural office	Extension service	Market advise	Minimal PH work

Annex Table 14. Supporting institutions and their respective roles in production, marketing and postharvest of sorghum, in Fedis Woreda

#	Name of supporting institution	Activities		
		Production	Marketing	Postharvest
1	FAO	NA	NA	Training for DA's, Farmers artisans to construct metal silos
2	Omo microfinance	Loan for inputs	NA	NA
3	Care Ethiopia	NA	NA	Facilitate distribution of super bags to farmers
4	Woreda agricultural offices with FTCs	Extension service	Market advise	Minimal PH work
5	Woreda cooperative promotion agency	Supply agricultural inputs	Facilitate marketing	NA
6	Fadis agricultural research center	Conduct research to increase yield	NA	NA
7	Haramaya University demonstration center	Research and extension service	NA	NA
8	WFP	Early warning support		
	ISM project- Integrated Striga management project	To control striga in sorghum	NA	NA

Annex Table 15. Cost-benefit analysis for Super Grain bag and PICS to store sorghum

Alphabet	Item	Unit	Calculation formula	Profit of solution	Remark	Remarks how it is calculated
a	Product quantity	tons/year		2.48	average value of three woredas for a farmer per hectare	Out of 3.16 tons (average of 4 woredas), only 78.47 % goes to storage i.e Total production minus non-storage related losses
b	Product value	$/ton		253.05	Average price of three woredas	Table 35
c	Loss rate	%		0.113	Average storage related loss of three woredas (11.3%)	Table 34a-Table 34d
d	Anticipated loss reduction	%		0.95	By 95 % of storage associated loses	Using hermetic bags during storage at least 80% of losses can be reduced
e	Cost of intervention	$		59.85	The average price for a bag is 1.71 $/bag *35 bags for 2.48 t of grain.	To store 2.48 tons of maize in hermetic bags = 2480 kg * 70 kg /bag = 35 bags
f	Depreciation	years		5	5 years estimated service life of hermetic bags with max care	
g	Yearly costs of investment	$/year	e **/** f	11.97		
h	Yearly costs of operation	$/year		0	no yearly cost of operation	
i	Total yearly costs of solution	$/year	g **+** h	11.97		
j	Client costs/ ton product	$/ton	i **/** a	4.83		
k	Food loss	tons/year	c x a	0.28	per hectare per a farmer	
l	Economic loss	$/year	k x b	70.90		
m	Loss reduction	tons/year	k **x** d	0.27		
n	Loss reduction savings	$/year	m x b	67.4		
o	Total Client costs	$/year	i = a x j	29.7		
p	Profitability of solution	$/year	n **-** o	37.7	By storing grains in hermetic bags storage losses can be reduced by 95% and a profit of 37.7 USD per year can be obtained.	

Annex Table 16. Cost-benefit analysis for metal silo to store sorghum

Alphabets	Item	Unit	Calculation formula	Profit of solution	Remark	Remarks how it is calculated
a	Product quantity	tons/year		2.48	average value of three woredas for a farmer per hectare	out of 3.16 tons (average of 4 woredas) only 78.47 % goes to storage i.e Total production minus non storage related losses
b	Product value	$/ton		253.05	Average price of three woredas	Table 35
c	Loss rate	%		0.113	Average storage related loss of three woredas (11.3%)	Table 34a-Table 34d
d	Anticipated loss reduction	%		0.95	By 95 % of storage associated loses	Using metal silo during storage at least 95% of losses can be reduced
e	Cost of intervention	$		439	Average price of metal silo = 4500 ETB with 20.5 USD for 1000 kg	price of one metal silo for one ton capacity = 4500 ETB = 4500/20.5 = 219.5 USD
f	Depreciation	years		15	15 years estimated service life of silo with maximum care	
g	Yearly costs of investment	$/year	e **/** f	29.3		
h	Yearly costs of operation	$/year		0	no yearly cost of operation	
i	Total yearly costs of solution	$/year	g **+** h	29.3		
j	Client costs / ton product	$/ton	i **/** a	11.8		
k	Food loss	tons/yr	c x a	0.28	per hectare per a farmer	
l	Economic loss	$/yr	k x b	70.90		
m	Loss reduction	ton/yr	k **x**d	0.27		
n	Loss reduction savings	$/year	m x b	67.4		
o	Total Client costs	$/year	i = a x j	72.6		
p	Profitability of solution	$/year	n **-** o	-5.2	By storing grains in hermetic bags storage losses can be reduced by 80% and a profit of-5.2 USD per year can be encored	

Annex Table 17. Institutions involved in pre-harvesting, postharvest and marketing activities (Summary of three woredas, Tach Gaint, Adami Tulu Gido Kombolcha, and Lok Abaya)-Haricot Bean

#	Name of institution	Support / Activities		
		Preharvest	**Postharvest**	**Marketing**
1	Credit and Saving S.C	Loan for purchase of agricultural inputs	NA	NA
2	Micro finance	Loan for purchase of agricultural inputs	NA	NA
3	Primary farmers cooperative	Purchase of grains from farmers	NA	supply of purchased grains to farmers unions
4	Farmers Union	Supply of agricultural inputs (seed, fertilizers)	Cleaning of grains	supply to central market (ECX)
5	Agricultural offices	Extension service mainly focusing on preharvest aspects	Advise on use of storage insect pesticides	Monitor non licensed and certified local collectors not to buy Haricot beans
6	District agricultural offices	Facilitate credit and supply of agricultural inputs	NA	Market study and provide market information to farmers
7	Ethiopia Agricultural Research Institute	Conduct research to improve productivity	NA	NA
8	FAO Ethiopia	NA	Offer training in areas of postharvest management	NA

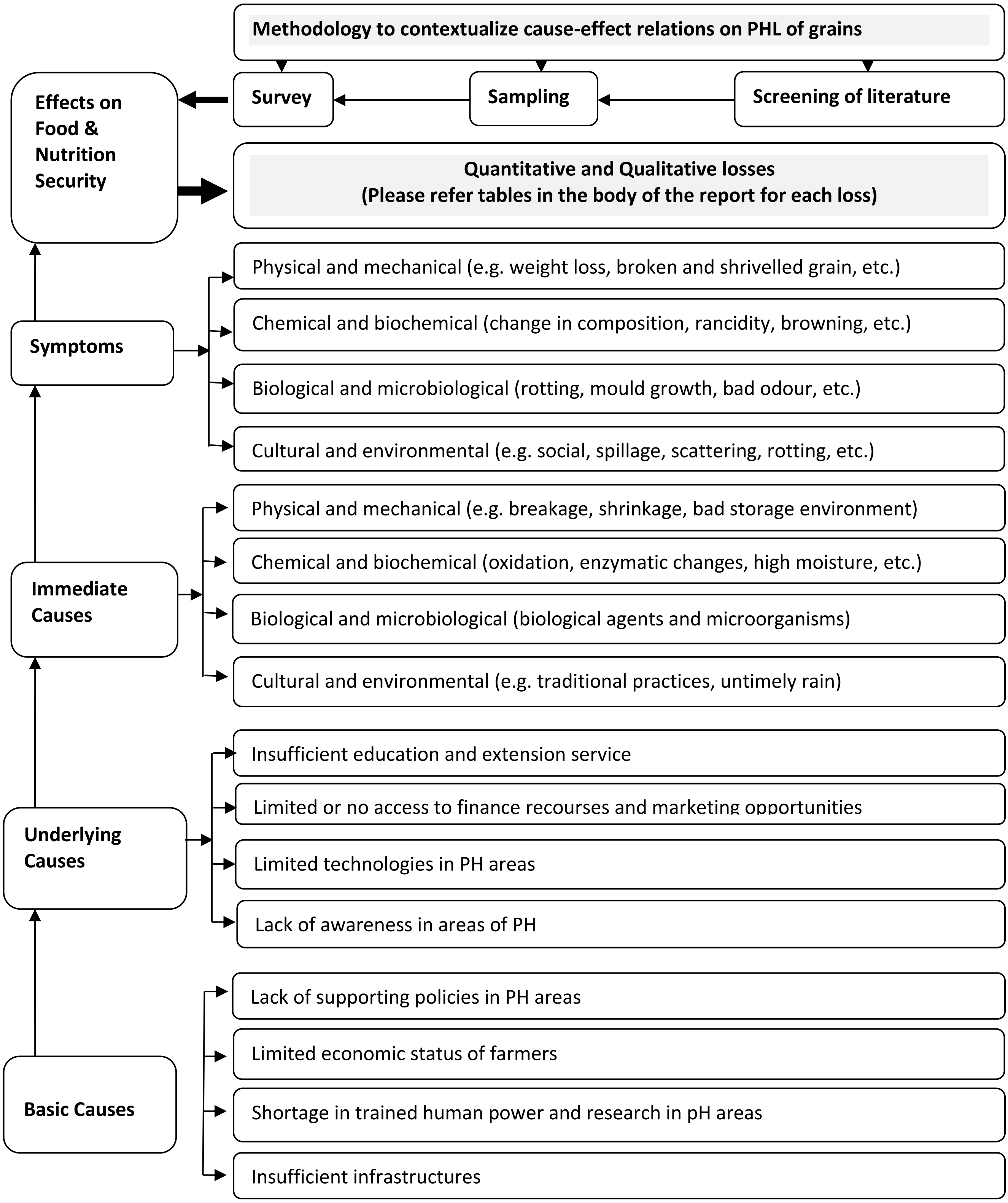
Annex Table 18. Cost-benefit analysis for Super Grain bag and PICS to store Haricot bean

Haricot bean	Item	Unit	Calculation formula	Profit of solution	Remarks	Description
a	Product quantity	tons/yr		1.18	average value of three woredas for a farmer per hectare	out of 1.45 tons (average of 3 woredas) only 81.6 % goes to storage (average) i.e total production minus non-storage related losses
b	Product value	USD/ton		265	Average price of three woredas in 2015	
c	Loss rate	%		0.083	Average of three woredas (8.3%)	
d	Anticipated loss reduction	%		0.95	By 95 % of storage associated losses	
e	Cost of intervention	USD		30.78	Average price per bag 1.71USD *18 bags for 1.18 ton of grain	Assuming that one bag can store 70 kg grain
f	Depreciation	years		5	5 years service	
g	Yearly costs of investment	USD/yr	e **/** f	6.156		
h	Yearly costs of operation	USD/yr		0	no annual operation cost	
i	Total yearly costs of solution	USD/yr	g **+** h	6.2		
j	Client costs /ton product	USD/ton	i **/** a	5.20		
k	Food loss	tons/year	c x a	0.10	per hectare per a farmer	
l	Economic loss	USD/year	k **x**b	26.03		
m	Loss reduction	tons/year	k **x**d	0.09		
n	Loss reduction savings	USD/year	m x b	24.7		
o	Total Client costs	USD/year	i = a x j	6.156		
p	Profitability of solution	USD/year	n **-** o	18.6	By storing grains in hermetic bags, storage losses can be reduced by 95% and a profit of 18.6 USD per year can be gained. Also the family becomes food secure.	

Annex Table 19. Cost-benefit analysis for galvanized Metal silo to store Haricot bean

code	Item	Unit	Calculation formula	Profit of solution	Remarks	Description
a	Product quantity	ton/yr		1.18	average value of three woredas for a farmer per hectare	out of 1.45 tons (average of 3 woredas) only 81.6 % is stored (average) i.e Total production minus non-storage related losses
b	Product value	USD/ton		265	Average price of 3 woredas in 2015	
c	Loss rate	%		0.083	Average of 3 woredas (8.3%)	
d	Anticipated loss reduction	%		0.95	By 95 % of storage associated loses	
e	Cost of intervention	USD		219.5	To store 1 ton HB in metal silo Assume 1 metal silos = 4500 ETB/silo * 1USD/20.5 ETB*1silo=219.5	
f	Depreciation	years		15	15 years service	
g	Yearly costs of investment	USD/yr	e **/** f	14.63		
h	Yearly costs of operation	USD/yr		0	no yearly cost of operation	
i	Total yearly costs of solution	USD/yr	g **+** h	14.6		
j	Client costs per ton product	USD/ton	i **/** a	12.36		
k	Food loss	t/yr	c x a	0.10	per hectare per farmer	
l	Economic loss	USD/yr	k **x**b	26.03		
m	Loss reduction	ton/yr	k **x**d	0.09		
n	Loss reduction savings	USD/yr	m x b	24.7		
o	Total Client costs	USD/yr	i = a x j	14.63		
p	Profitability of solution	USD/yr	n **-** o	10.1	storing grains in metal silos can reduce loss by 95% & provide a profit of 10.1USD/yr. Also the family becomes food secure.	

Annex 2. Figures



Annex Figure 1. Cause finding diagram for grain crops

Annex 3. Load Tracking of postharvest loss of grains during milling

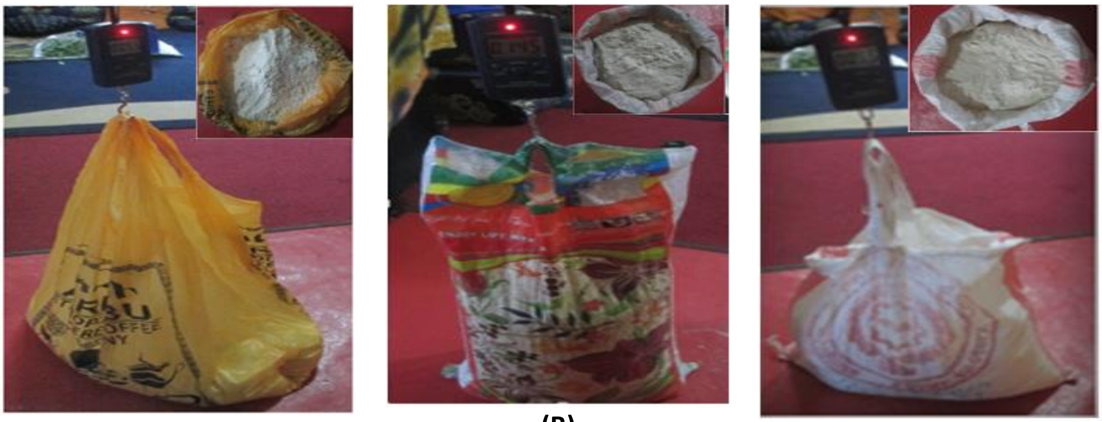
In order to visualize the extent of postharvest loss incurred during village level small scale processing of grains at the local flour mill, a load tracking was done In Jimma Town very close to that of Darimum Woreda. The mills are so small having a capacity of 80-100kg/hr owned often by individuals but there are cases where cooperatives and churches providing this kind of service. Three types of grain crops were used for the assessment (wheat, maize and sorghum). The grains were purchased from the local retail market, though grains could have been purchased from the flour mill owners as well, and kept in three separate bags (Figure 1 and 2).

(A) (B) (C)

Figure 1. Samples of (A)-Maize, (B)-Sorghum and (C)-wheat) ready for load tracking during milling at the local flour Mill in Jimma town close to Darimu woreda, Ethiopia

In order to begin the load tracking process, a volunteer lady was invited to go through all the steps that they usually do in order to get whole mill flour ready for consumption of the three grain types separately. Cleaning can be done at home or at the milling station in which one can get a hired labour (often male) to clean the grains for clients with a reasonable charge (10-15 ETB/100kg). The initial weight of the samples was taken before and after cleaning. The cull was separated again into edible and non-edible groups and weight of each was taken separately. Once again, the net weight of the clean sample was taken and then submitted for milling at the local flour Mill. The flour for each of the grains was collected and weighed (Figure 3).

Figure 2. A typical local flour Mill in Jimma Town near Darimu woreda, Ethiopia



(A) (B) (C)

Figure 3. Weight of the flour for (A)-Maize, (B)-Sorghum and (C)-wheat after milling at the local flour Mill in Jimma town close to Darimu woreda, Ethiopia

After registering the weight, each flour was sifted to separate the bran, other non-edible staff and partly milled grains (Figure 5). Finally, the weight of edible and non-edible sift was registered.

Figure 4. Sifting of the four to separate the bran and partly milled grains

The results in Figure 5 reveal that the extent of postharvest loss incurred during flour milling was unbelievably high. The loss during milling is a function of many factors including the initial quality of the grain, the moisture content of the kernels, the efficiency of the milling machine, the person involved in the cleaning, milling, and sifting process. The critical loss point for wheat, maize and sorghum were at Milling and sieving. The cumulative lass from cleaning through milling to sifting was

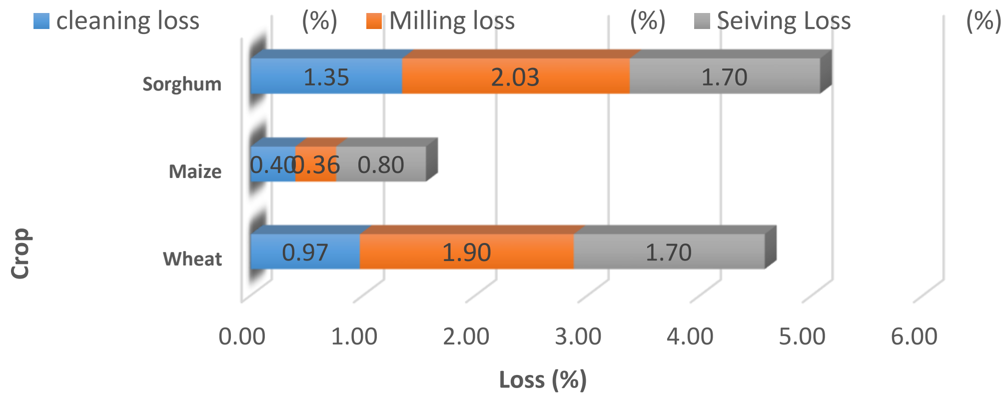


Figure 1. Extent of Postharvest loss during processing at the local flour mill

4.58, 1.56 and 5.07% for wheat, maize and sorghum respectively. In Kenya, the extent of postharvest loss at small scale processor level was reported to be 3.5% (FAO, 2014) which is almost double what we have observed in our load tracking. Since the load tracking was done only at one milling station, the results should be interpreted with caution and a well-replicated assessment would be recommended before we could arrive at a concrete conclusion. However, the findings from the present load tracking are indicative of the need to monitor and regulate the local milling stations in view of food safety and reduction of postharvest losses.

Annex 4. Some additional pictures

At the central market in Addis local called *"Ehil Tera"* traders experience loss grains because of bird and rodent damage

Figure .. At times, farmers move their harvest to the Threshing area using donkey or horse carts

A farmer in Alamata, Tigray demonstrating pit storage of sorghum

A typical mold contaminated sorghum from a pit storage in one of the woredas

Farmers use a locally made pronged wood to separate the grain from the straw after threshing wheat, teff, barley, etc.