Post-harvest wheat losses in Africa: an Ethiopian case study

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1 Introduction

Wheat is one of the major cereals and a staple crop in Africa. Demand for wheat is increasing in sub-Saharan Africa because of income growth, urbanization and dietary diversification (Jayne et al., 2010a; Negassa et al., 2013). Sub-Saharan countries and Africa as a whole produce only about 30% and 40% of their domestic requirements, respectively (Negassa et al., 2013). This results in heavy dependence on imports which makes the region highly vulnerable to global market and supply shocks. In Ethiopia in 2013 wheat was cultivated on 1.7 million ha, with an annual production of 4.04 million tons (Fig. 1) (FAOSTAT, 2015). This represented the largest area of cultivation and highest overall production in sub-Saharan Africa (Table 1). Wheat is grown by more than 4.7 million smallholder farmers in Ethiopia. It is the third most important crop in terms of production, after teff (a grain crop) and maize, and the fourth most important crop in area coverage, after teff, maize and

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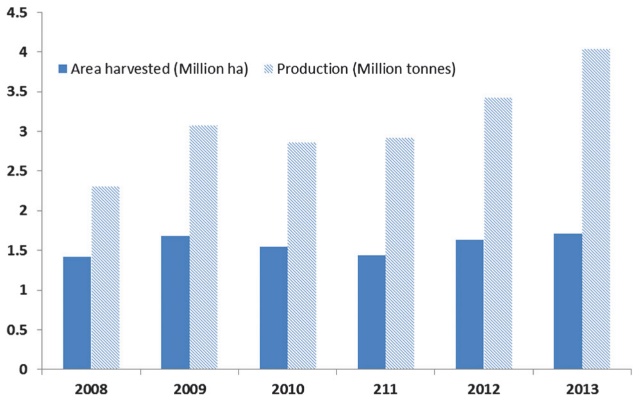

Figure 1 Area and production of wheat in Ethiopia during 2008–2013. (FAOSTAT, http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor, accessed February 2015). The new website is http://faostat3.fao.org.

Table 1 Area (ha), production (tonnes) and rank of wheat in selected countries in sub-Saharan Africa (FAOSTAT, accessed February 2015)

	2011		2012		2013		
Countries	Area	Production	Area	Production	Area	Production	Rank
Angola	3650	4000	3400	4000	3420	3958	
Burundi	11500	9787	9434	4196	8828	6423	
Ethiopia	1437485	2916334	1627647	3434706	1706324	4039113	1
Kenya	131509	268482	148703	441754	160000	485846	3
Malawi	1216	1850	1295	1956	1269	1784	
Mali	9844	33842	10349	40071	6900	27430	
Nigeria	99000	165000	90000	100000	80000	80000	
South Africa	604700	2005000	511000	1915000	500000	1760000	2
Uganda	13000	23000	14000	20000	14200	20000	
Zambia	37631	237332	37209	253522	41810	273584	
Zimbabwe	12000	23000	11000	20000	10000	25000	

sorghum (CSA, 2013). Wheat production is steadily increasing despite serious constraints such as recurrent epidemics of diseases such as rusts and *Septoria* (Singh et al., 2008; Teferi and Gebreslassie, 2015).

Ethiopia's wheat farmers are the greatest producer of wheat in sub-Saharan Africa (Table 1), yet Ethiopia is not self-sufficient in its wheat production and imports an average of more than 1 million tons per annum (Index Mundi, 2016). Once a net exporter of wheat, Ethiopia is now a net importer of wheat due to many factors including war and crop failures (Hailu, 1991), as well as population growth outpacing increases in production (Reuben et al., 2005). Increasing yield is frequently cited as an important issue for increasing food security (Adugna et al., 1991; Hailu, 1991; van Keulen and Hengsdijk, 2005; Bekele et al., 2009; Jayne et al., 2010b).

Wheat in Ethiopia is predominantly grown in the midland to highland regions of the country, at elevations of 1900–2700 m, in temperatures ranging from 6 to 23°C, with annual rainfall of 35–180 mm (Hailu, 1991; White et al., 2001). Since wheat is mainly a rainfed crop, wheat growers utilize the long rainy season (Meher). This is the main growing season which starts in June and lasts until the rains begin to decrease in October, with the wheat harvest starting in December (Hailu, 1991; White et al., 2001). The soil types found in these areas are clay-rich Vertisols, less clay-rich Nitisols, black soils, red soils and brown soils, which have their own input needs (Asnakew et al., 1991; White et al., 2001).

Increasing domestic production to meet local demands is not enough to make Ethiopia self-sufficient in wheat production. A more meaningful means of improving food security in sub-Saharan Africa would be to improve post-harvest protection practices aimed at protecting the harvested wheat throughout the wheat value chain (Negassa, et al., 2013; World Bank, 2011). Understanding where improvements can be made, and how best to make them, will optimize efforts in these areas. However, but there are gaps in available data (Affognon et al., 2015). These gaps need to be filled if a programme to improve food security in Ethiopia is to be as successful as a recent post-harvest loss eradication programme in Uganda by World Food Programme (Costa, 2015).

Post-harvest losses can be quantitative (e.g. reduced volume or weight of grain), qualitative (e.g. loss of nutritional or processing quality, including contamination with aflatoxins) and economic (e.g. reduced value or access to some markets). According to estimates provided by the African Postharvest Losses Information System (APHLIS), physical grain losses range from 10 to 20% (www.aphlis.net). It has been estimated that overall post-harvest grain losses for sub-Saharan Africa could be as high as US$4 billion/year, around 15% of total production (World Bank, 2011). This compares to the findings reported for post-harvest losses of wheat in Ethiopia discussed later in this chapter. These suggest high average losses of around 17%, with losses ranging from 14 to as high as 23%.

Post-harvest loss can occur at any stage along the post-harvest value chain. Understanding the circumstances around harvest and post-harvest operations for a given crop will help reduce post-harvest losses and improve the income of farm households. Improvements in post-harvest management practices will help avoid both quantitative and qualitative losses and maintain the quality of the grain for various end uses. It is necessary to develop effective strategies for the post-harvest value chain (field to market) that avoid deterioration in wheat grain quantity and quality, satisfy market demands, and improve the income and food security of smallholder farmers. Reduction in wheat post-harvest losses will also help to offset the costs of importing wheat.

In order to better understand post-harvest issues of Ethiopian wheat farmers, a questionnaire-based survey was conducted in 2014 to understand farmer perceptions about wheat production, potential sources of post-harvest losses from harvesting to marketing and post-harvest loss mitigation measures used by farmers, as well as post-harvest protection information needs. The survey was part of a project funded for a five-year period (2014–2018) by the United States Agency for International Development. This project resulted in setting up of the Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss at Kansas State University, Manhattan, Kansas. The Ethiopian part of the project was also supported by funds from the ADM Institute for Prevention of Postharvest

Loss, University of Illinois, Urbana-Champaign, Illinois. Our work builds on previous surveys of Ethiopian grain farmers by Blum and Bekele (2001), Abebe and Bekele (2003), Pender and Gebremedhin (2006), and Gebremedhin and Hoekstra (2007).

2 Methods

The study was conducted in November 2014. It surveyed wheat growers from four regions of Ethiopia: the Oromia, Amhara, and Tigray regions and the Southern Nations Nationalities and Peoples (SNNP) region. The top 100 wheat growing zones and districts are located in these four regions (Warner et al., 2015). A 13-page survey questionnaire with 65 questions was used to collect primary data from wheat farmers in the study areas. The first and second stages involved a selection of zones and districts that are representative of wheat-based farming systems. Fourteen villages were selected for the study. Carefully selected enumerators pre-tested the questionnaire and later collected data on input use, outputs, post-harvest losses, and socio-economic and farm characteristics. The 200 respondents were from highland (21%), midland (73%) and lowland (6%) ecological zones. The interviews were conducted using structured and semi-structured formats. The estimation of post-harvest losses was carried out using SPSS software (SPSS, 2009) and the post-harvest loss online calculator developed by APHLIS (Hodges et al., 2011, 2014).

3 Demographics

The survey asked numerous questions including gender of household head, number of household members, number of children, size of farm and distance to nearest market.

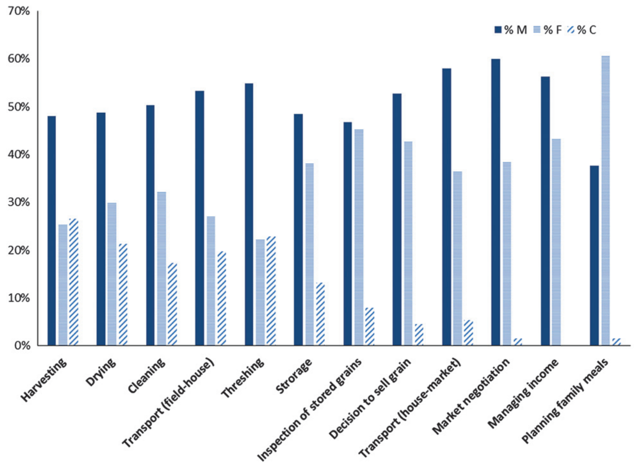

Figure 2 Post-harvest and household division of labour (percentage) by males (solid dark blue), females (solid light blue) and children (diagonal mid-blue).

Participation in post-harvest activities was also included. The age of the household's head, family size and wheat farm size showed variation across the regions studied. The average age of the surveyed wheat farmers was 43 years, but the ages ranged from 20 to 87 years (Table 2). The average farm household had a total of six members.

Farmers had an average of 1.42 ha of land for wheat cultivation during 2014–15. The minimum and the maximum land owned for wheat by the sampled households were 0.13 ha in Amhara and 8 ha in Oromia. Farmers in Oromia, on average, allotted more land for wheat cultivation (2.17 ha) compared to farmers in SNNP (1.1 ha), Amhara (1 ha) and Tigray (0.56 ha). The average distance from home to the nearest market centre was 7 km, with a minimum of less than 1 km, for all regions. The maximum distance reported was 45 km in Amhara. Generally, the wheat farmers in SNNP region travelled shorter distances to market than the other regions. Respondents who reported 0 km distance to the nearest market may have traders coming to the farm gate or village, as is the case for maize growers in Malawi, Zambia and Kenya (Jayne et al., 2010a).

Of the 200 respondents, 92% of households were headed by males and only 8% by females. Men play a major role in wheat harvesting, drying, cleaning, transportation from the field to the farm, threshing, storage, the decision to sell the grain, transportation from

Table 2 Socio-economic characteristics of sampled wheat farmers

Region	Variables	Mean	*N*	Minimum	Maximum
Tigray	Age of the household head	44.2	30	28	68
	Family size	6.8	30	2	10
	Proximity to the nearest market (Km)	7.7	23	0	30
	Wheat farm size (ha)	0.56	30	0.25	2.9
Amhara	Age of the household head	47.2	66	24	78
	Family size	6	66	2	13
	Proximity to the nearest market (Km)	7.1	63	0	45
	Wheat farm size (ha)	1	66	0.13	3
Oromia	Age of the household head	40.7	80	20	87
	Family size	7.2	79	1	21
	Proximity to the nearest market (Km)	7.0	73	0	20
	Wheat farm size (ha)	2.17	79	0.25	8
SNNP	Age of the household head	34.7	15	25	58
	Family size	7.6	15	5	11
	Proximity to the nearest market (Km)	5.7	13	0	15
	Wheat farm size (ha)	1.1	15	0.5	2
Total	Age of the household head	43	191	20	87
	Family size	6.7	190	1	21
	Proximity to the nearest market (Km)	7.0	172	0	45
	Wheat farm size (ha)	1.42	190	0.13	8

homes to the market, market negotiations and managing income (Fig. 2). Both men and women play an equal role in inspecting stored wheat, and women play a major role in planning family meals. Children play a slightly bigger role in harvesting and threshing than women, but their role is minimal in all other post-harvest operations.

4 Crop production information

The following is an overview on farm production by wheat growers in the regions covered by our survey. Crop production is the main source of income for wheat producing farmers. About 82% of respondents had livestock which provided secondary source of income. Twenty-five different varieties of bread and durum wheat were grown in the studied zones across the four regions (data not shown), but there were five main varieties grown across the four study regions (Table 3). Varietal variation of wheat produced across the studied regions reflects subtle differences in local climates, soil types, and grower's needs and priorities (White et al., 2001; Pender and Gebremedhin, 2006; Negassa et al., 2013).

The main selection criteria of wheat varieties from our survey by farmers were seed price, seed availability, productivity, followed by length of crop cycle and stress resistance (Table 4). There was no distinction between insect resistance in the field or during storage. Grain colour was considered the most important criterion for choosing grain for consumption by 91% of respondents, closely followed by kernel size (Danielsen et al., 2014).

Respondents to the survey practised mixed farming, with bread wheat, maize, teff, faba bean, potato, pepper and finger millet being the major crops grown in the 2013/2014 cropping period (Fig. 3). Devereux et al. (2008) noted that even if families can produce a surplus on their land, they will sell most of their crops in order to purchase more calorific and nutritious foods than those they grow. The available literature does not indicate that this practice has changed since the 2006–2008 global food crisis, suggesting that increasing costs of food, from the main harvest period, are outweighed by the benefits of a varied diet, which helps in reducing malnutrition and undernutrition, especially in children below five years of age (Ali et al., 2012; Nguyen et al., 2013; Jones et al., 2014; Ford and Stein, 2016). Mean productivity of the different zones was highest at Arsi, Oromia region (4.1 ton ha^{-1}), followed by Hadia, SNNP region (3.9 ton ha^{-1}), and Semen Shewa, Amhara region (3.8 ton ha^{-1}). The lowest productivity was recorded at western Arsi, Oromia region (2.3 ton ha^{-1}), and eastern Tigray, Tigray region (2.1 ton ha^{-1}).

Table 3 Main wheat varieties, by region

Region	Variety	Number of respondents (%)
Amhara	Kekeba	78 (62)
Oromia	Digalu and Kubsa	114 (25 and 25)
Tigray	Danda'a	14 (57)
SNNP	Digalu	21 (43)

Table 4 Criteria used to select wheat varieties

	Criteria	*N*	Percentage
Farmers	Cost of seed	182	91
	Crop demonstration/research data	14	7
	Disease resistance	92	46
	Drought resistance	110	55
	End use quality	66	33
	Growing period	116	58
	Insect resistance	112	56
	Lodging[1] resistance	75	37.5
	Only variety known	62	31
	Resistance to water logging	94	47
	Salt tolerance	72	36
	Yield per hectare	139	69.5
Cooks	Grain colour	172	91
	Grain not damaged or crushed	153	83
	Grain not damaged by insects	166	66
	Grain not stained	155	85
	Kernel size	161	87

[1]In machinery

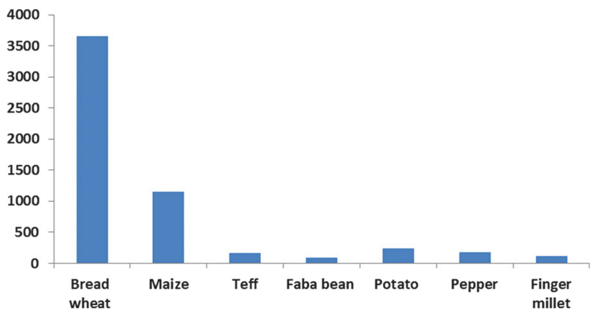

Figure 3 Crop production of surveyed farmers 2013/2014 (tons).

5 Post-harvest issues

The post-harvest period begins when wheat is harvested and ends with sales or consumption of grains. The 'how' and 'where' losses occur will be discussed in this section, followed by 'who does what' as well as current methods of managing post-harvest losses. The losses (kg ha^{-1}) were estimated across wheat zones in different regions (Table 5) based on the

Table 5 Post-harvest loss estimates (kg ha^{-1}) in different zones in surveyed regions

	Tigray		Amhara			Oromia			SNNP	
PH stages	SE Tigray	Eastern Tigray	West Gojam	East Gojam	Semen Shewa	Arsi	West Arsi	Bale	Hadiya	Mean
Harvesting	230.2	142.2	237.0	203.1	257.3	277.6	155.7	223.4	264.0	221.2
Threshing	119.0	73.5	122.5	105.0	133.0	143.5	80.5	115.5	136.5	114.3
Cleaning	72.1	44.5	74.2	63.6	80.6	86.9	48.8	70.0	82.7	69.3
Packaging/bagging	5.4	3.4	5.6	4.8	6.1	6.6	3.7	5.3	6.2	5.2
Transportation (farm to storage)	38.1	23.5	39.2	33.6	42.6	45.9	25.8	37.0	43.7	36.6
Farm storage	90.8	56.1	93.5	80.1	101.5	109.5	61.4	88.1	104.1	87.2
Transportation (storage to market)	6.8	4.2	7.0	6.0	7.6	8.2	4.6	6.6	7.8	6.5
Market storage	3.4	2.1	3.5	3.0	3.8	4.1	2.3	3.3	3.9	3.3
Milling/crushing/grinding	14.6	9.0	15.1	12.9	16.3	17.6	9.9	14.2	16.8	14.0
Total	579.7	358.1	596.8	511.5	647.9	699.1	392.2	562.7	665.0	557.0

overall yield potential. Mean losses across zones and regions were highest at harvesting (221 kg ha^{-1}), threshing (114 kg ha^{-1}) and during farm storage (87.2 kg ha^{-1}).

When wheat grain is handled at harvest and in the post-harvest chain, post-harvest losses occur from a number of different causes (Table 6). High grain moisture (11.8% of respondents), insects (11.6%) and rodents (11.1%) in storage were reported as major causes for post-harvest loss, although severity varied from region to region. The Oromia, Amhara and Tigray regions experienced the most post-harvest losses due to moisture or insects and rodents in storage.

The percentage post-harvest loss of wheat grain at different stages in post-harvest operations was estimated using SPSS, and using the post-harvest loss calculator for two

Table 6 Different causes of wheat post-harvest losses by region

	Count (*N*)	Region				
Variable	Percentage (%)	Tigray	Amhara	Oromia	SNNPR	Total
Broken kernel	N	20	10	21	3	54
	%	74.1	37	41.2	30	47
Harvesting method	N	18	15	39	10	82
	%	64.3	48.4	63.9	71.4	61.2
Insect in the field	N	20	21	52	5	98
	%	71.4	58.3	76.5	50	69
Insect in storage	N	25	50	51	2	128
	%	86.2	90.9	81	25	82.6
Moisture	N	25	45	51	9	130
	%	83.3	84.9	81	81.8	82.8
Mould in the field	N	20	9	12	2	43
	%	71.4	45	40	25	50
Mould in storage	N	19	8	19	2	48
	%	76	42.1	52.8	40	56.5
Rodents in the field	N	26	24	39	7	96
	%	89.7	63.2	67.2	87.5	72.2
Rodents in storage	N	27	39	50	7	123
	%	90	84.8	80.6	70	83.1
Spillage	N	17	2	27	4	50
	%	70.8	12.5	56.3	36.4	50.5
Threshing method	N	17	19	40	7	83
	%	65.4	54.3	64.5	53.8	61
Transportation	N	1	11	27	5	44
	%	12.5	55	56.3	45.5	50.6

Table 7 Estimated wheat post-harvest losses at different stages for all surveyed regions

			PHL calculator estimates at two scenarios[2]	
Harvest and PH stages	Wheat losses (%)[1]	N	No rain at harvesting	Rain at harvest
Harvesting	6.8	183	6.8	16.3
Threshing	3.5	178	3.5	3.5
Cleaning	2.1	175	–	–
Packaging/bagging	0.2	168	–	–
Transportation (farm to storage)	1.1	165	1.2	1.2
Farm storage	2.7	180	2.7	2.7
Transportation (storage to market)	0.2	165	1	1
Market storage	0.1	166	2.7	2.7
Milling/grinding	0.4	172	–	–
Total	17.1		14	23

[1] SPSS calculated.
[2] APHLIS online calculated.

Table 8 Post-harvest loss estimates for wheat in Ethiopian Birr (ETB) at harvest in the absence (NR) and presence (WR) of rain for the four regions in 2014. US$1 = 22 ETB

Region	Production (tonnes)	Average price (ETB/ tonne)	Estimated value (ETB)	Average weight loss (%)	Value of weight loss (NR) (ETB)	Average weight loss (%)	Value of weight loss (WR) (ETB)
Tigray	379.5	615.9	233,730	0.14	32,722	0.23	53,758
Amhara	2,060	615.9	1,268,795	0.14	177,631	0.23	279,134
Oromia	4,900	615.9	3,017,861	0.14	422,500	0.23	663,929
SNNPR	588	615.9	362,143	0.14	50,700	0.23	79,671

different scenarios (Table 7). Total post-harvest losses during various stages of handling was estimated to be high at 17.1%, ranging from 14 to 23%, depending on levels of rainfall. In all of the estimates, losses were highest at harvesting (6.8–16.3%), followed by threshing (3.5%) farm and market storage (2.7%). According to respondents, loss at harvesting was mainly due to shattering of the standing grains, if there was no rain at harvest. Excessive rain during harvest spoils the grains due to moulds because farmers leave the harvested stalks in the fields to dry in the sun.

The economic losses due to post-harvest weight loss for the Tigray, Amhara, Oromia and SNNP regions was estimated using APHLIS post-harvest loss calculator (Table 8). The monetary losses that resulted from grain weight loss were Ethiopian Birs or ETB 32 722, ETB 177 631, ETB 422 500 and ETB 50 700 for Tigray, Amhara, Oromia and South regions, respectively, when no rain occurred during harvesting. If rain occurs during harvesting, losses increase significantly.

Figure 4 Two gotera, traditional storage units.

Harvesting methods for the sampled wheat farming households were: traditional manual techniques in the Tigray region; 95% traditional in the Amhara region with 5% using combine harvesters; and, in the Oromia region, 80% using combine harvesters and 20% traditional methods. There was no data on harvesting methods in SNNP. The majority of surveyed farmers used oxen for threshing, with some losses due to oxen eating grains. The oxen also urinate and defecate while trampling the grain during threshing. Grain losses during cleaning was marginal, accounted for about 2%.

At harvest farmers determine grain moisture by biting the kernel. Farmers expressed their interest in monitoring moisture control at storage using a moisture meter and dryer if the price of the moisture meter was not a limiting factor. If each woreda (district) or kebele (peasant association) had cooperatively owned dryers, wheat farmers who belonged to these organizations would be able to achieve consistent levels of dryness in their grain. For smallholder farmers, who are more likely to dry their wheat in the sun, harvest timing was important so that the threshed wheat could dry sufficiently. Before wheat can be stored, it needs to be dried to prevent moulds and mycotoxin production and reduce insect damage. Wheat growers in Ethiopia predominantly rely on solar/sun drying. However, there are cabinet dryers used for drying fruits and vegetables and these are currently being modified and optimized to dry grains.

Harvested grain should be stored properly to prevent damage by insects and moulds during storage. Several species of stored product insects and moulds have been reported from wheat and other grains in Ethiopia. Abraham et al. (2008) has provided a comprehensive review of insect pests and moulds associated with stored grains in Ethiopia. Traditional storage units, such as gota, gotera and underground pits (Fig. 4) are suboptimal storage facilities (Blum and Bekele, 2001; Tefera et al., 2011; Costa, 2014), because these structures can be easily infested by insects and rodents, and mould damage is common in improperly dried grains and in grains stored in underground pits because of seepage of moisture. The most popular storage methods were fertilizer bags, gotera (traditional storage structures made from plant materials), jute bags, polypropylene bags and warehouses (Fig. 5). Most farmers reported inspecting their grain once a month using visual and olfactory senses (e.g. to check colour or smell). Respondents stored grain for between 3 to 12 months for different purposes, including consumption, later sale, for seed or for storing surpluses after a big harvest.

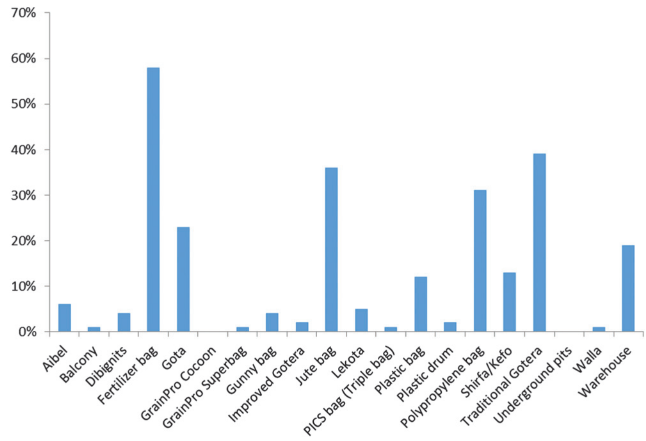

Figure 5 Methods of storing grain (percentages based on 200 farmers).

The storage methods used by respondents vary in their effectiveness and affordability. As previously mentioned, insects play a major role in deterioration of stored wheat grains and post-harvest losses and control measures for these pests need to be devised to minimize post-harvest losses. Gotera are better than nothing, but are not optimal as they are not hermetic and grains are still affected by insect pests and moulds (Costa, 2014). Hermetic forms of storage, e.g. Purdue Improved Crop Storage (PICS) bags, are only effective when used properly. Without training hermetic bags are not properly used (Costa, 2015) and uptake of PICS and similar technologies is limited (Ibro et al., 2014). Once training is provided, post-harvest losses decrease dramatically (Costa, 2014, 2015; Moussa et al., 2014).

Farmers who store their wheat use different storage control methods in order to minimize and avoid losses during storage (Table 9). Among the different kinds of storage

Table 9 Methods used to control storage losses

Method	Percentage usage
Traditional herbs	10
Mix with teff	2
Mix with ashes	2
Mix with sawdust	2
Filter cake	1
Actellic dust	27
Malathion dust	28
Fumigant (phosphine)	35
Fungicides	6
Smoking	6
Drying	79

Table 10 Factors affecting selection of control methods

Factor for selection	Respondents (%)
Traditional practice or custom	79
Ease of use	53
Locally available materials	39
Effectiveness of method	30
Affordable price	28
Prior positive results	17
Received training on	10
Others	7

control methods, 79% of the surveyed farmers use drying, as previously mentioned. Fumigation was the second most popular method for controlling losses from insects. Farmers' preference to select a given control method depended on different factors. These included traditional practices, ease of use, locally availability of the material, control effectiveness and affordability (Table 10).

Lack of training in the use of specific technologies is not always the main issue compared to access to technologies. Costa (2015) found the uptake of metal silos was influenced by farmers' ability to get the silo to their farm. If farmers had to travel to collect a silo, they would be less likely to do so, but a silo delivered to their farm was utilized. There may be similar issues with distance and transportability among respondents to our survey as the average distance to economic centres was 7 km. Farmers do not all have the means of transporting large objects such as a family-size metal silo.

Not all farmers store their wheat; many sell their wheat right after harvest because of an urgent need for cash (Abebe and Bekele, 2003). Cash is needed to pay loans and taxes, even if prices for grains right after harvest are lower than prices in 3–6 months after harvest (Abebe and Bekele, 2003). Farmers allocate cash from grain sales to a diverse range of household needs. Different expenditures indicated by respondents were for clothing, children's education, food, celebrating holidays and savings (Fig. 6). Money for business investment is scarce, indicating the income is insufficient to start such activities. Ethiopian farmers have access to credit systems, but this often involves poorer farmers using credit for food or agricultural inputs, while the poorest cannot access credit systems at all because they lack sufficient collateral (Uraguchi, 2010; World Bank, 2011; Tadesse, 2014; World Bank Group, 2016).

Those farmers that do sell wheat either have to travel to the nearest market or use traders who come directly to the farm gate (Jayne et al., 2010a). Jayne et al. (2010a) found maize growers in Zambia, Kenya and Malawi receive 60–90% of the retail value for their grain from grain traders, indicating a need for greater training in marketing and negotiation among grain growers. The probability that a grain grower owns a mobile phone has been found to increase with increasing distance from markets (Tadesse and Bahiigwa, 2015). Various circumstances may prevent farmers from selling their grain. These range from reluctance to sell due to poor or fluctuating market prices, home consumption, retaining seed for the next season and the need for emergency grain when other food sources were insufficient. The long-term effect of multiple poor harvests is annual reductions in

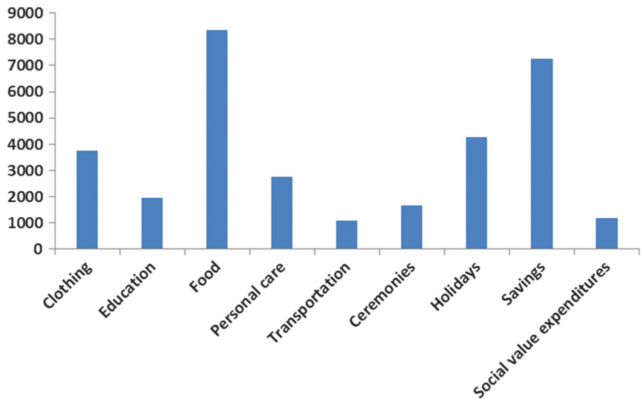

Figure 6 Annual household budget allocations (ETB) (US$1 = 22 ETB).

income, with corresponding reductions in spending or selling off assets (Devereux et al., 2008). Information on where reductions might occur was not collected in our survey. Uraguchi (2010) found Ethiopian and Bangladeshi households affected by the 2007–2008 food price hikes allocated more time looking for cheaper food, reduced the quality and variety of foods consumed, while 16% of Ethiopian households removed children from school.

Respondents said the price of wheat grain varied from ETB 400–900 during the season – the highest prices were noted after storage and reached ETB 1000–1500 at some marketplaces. This level of price variation indicates wheat growers would benefit greatly from either improved on-farm storage practices or warehouse storage systems (Abebe and Bekele, 2003; Jayne et al., 2010b). Farmers who owned cell phones were more likely to sell their grain to traders than cooperatives (Tadesse and Bahiigwa, 2015).

Budget allocations for household and farm were considered separately. For the year of the survey, the averages for fertilizer and herbicide expenditure were ETB 2523 and ETB 1683, respectively (N = 191 farmers). Widely used varieties of wheat often require extra inputs to reach their production potential, mostly fertilizers (Adugna et al., 1991; Negassa et al., 2013) which are not always affordable or easily accessible (unless they are organic fertilizers, which can conflict with other needs – animal feed, cooking fuel, etc.) (Assefa, 2005; Tadesse, 2014).

At the time of our survey, respondents said grain unfit for human consumption was mostly fed to animals. Blum and Bekele (2001) found some farmers could not afford to waste any grain and ate damaged grain themselves. The effects on their health depend on the type of damage to the grain. Insect damage reduces the nutritional quality of the grain, while grains affected by moulds such as aflatoxins can make consumers very ill (Wagacha and Muthomi, 2008). Illness from eating damaged wheat was reported by 3% of the respondents to our survey, but they did not specify which household members or how many had been ill. Improving on-farm/in-house storage conditions for wheat will not only reduce post-harvest losses. It will reduce, if not eliminate, the frequency or need to consume damaged or contaminated grains, increasing food and nutritional security (Ali et al., 2012; Nguyen et al., 2013; Jones et al., 2014; Ford and Stein, 2016).

6 Preventing post-harvest losses

It is clear that post-harvest losses are an issue of national food security for Ethiopia. Reducing post-harvest losses across wheat growing regions requires awareness of the issues, plus a variety of inputs and strategies, which are discussed below.

7 Information flow and training requirements

As far as current trends in provision of information and training to farmer training are concerned, respondents were unsatisfied with existing levels of support. They had a long list of needs. These included more information about weather conditions (particularly during the harvest period), better moisture measurement, better storage techniques (including using pesticides during storage) and better market information. Farmers expressed their eagerness to receive training in the future in these areas. When it came to training on post-harvest losses, more than half of the respondents (58%) claimed they had not received training or information in any form on post-harvest loss prevention.

This indicates that the awareness of the factors attributing to post-harvest loss was low among respondents, limiting their ability to take measures to reduce losses. Increasing farmer training through large meetings or farmer field schools can increase participants' food security (Larsen and Lilleør, 2014), especially if there is coverage of what most interests farmers. Increasing education and training in post-harvest loss reduction, and the research behind it, will require continued funding from local and international bodies (Kitinoja et al., 2011; World Bank, 2011). However, it is not just a case of providing more training opportunities or training in local languages. More targeted training is required in the areas specified by the respondents, including training targeted towards female farmers. Rugumamu (2009) found post-harvest losses experienced by maize farmers were a function of gender roles and technologies employed.

Ethiopia's wheat farmers, and all farmers across sub-Saharan Africa, would greatly benefit from reliable seasonal forecasts (Coe and Stern, 2011). Information on when rains are likely to start will help them decide when to harvest and how to dry their wheat, as the timing of the harvest affects the nutritional qualities of the grain. Respondents in Kassie et al. (2013) received most of their weather forecast information from village meetings but found the process unreliable.

Almost all wheat farmers were engaged or involved in one or more forms of farmers' organizations, that is, general cooperatives, unions, development associations, research or crop production groups, saving association, woman and youth associations. The different organizations have different purposes and services for the community. Farmers believed that the most trusted crop production and stored grain management information was received from development agents. Other organizations such as offices of agriculture at different levels, research centres, projects such as the East Africa Agricultural Productivity Project, neighbouring farmers, farmers training centres, seed enterprises and farmers' unions were also perceived as reliable sources of information about crop production. Ethiopia's long history of government-run extension programmes (Adugna et al., 1991) places government researchers, extension officers and farmers in good stead for further capacity building in post-harvest loss prevention (World Bank, 2011).

Table 11 Preferred methods for receiving information (N = 200)

	N	%
Cell phones	68	34
Demonstration trials	124	62
Fellow farmers	136	68
Input suppliers	89	44.5
Internet	52	26
Large meetings	176	88
One-on-one delivery	126	63
Printed materials	81	40.5
Radio programmes	127	63.5
Religious leaders	73	36.5
Television programmes	79	39.5

The five most preferred and used methods of receiving new information by farmers were large meetings, fellow farmers, radio programmes, one-on-one delivery and demonstration trials (Table 11). Grain traders also rely on radio programmes for supply and demand information, national policy changes and external market grain prices (Gabre-Madhin and Amha, 2005). Some educated farmers have used internet sources to gain information (Gebremedhin and Hoekstra, 2007; Bekele et al., 2009; World Bank, 2011). Tedesse and Bahiigwa (2015) observed that farmer age and education level were correlated with cell phone ownership and use, indicating that as younger, more educated farmers take over family farms, extension organizations might consider distributing some information via cell phones.

8 Gender and food security issues

It has been suggested that 'Capacity development is critical to achieving lasting change' (Costa, 2014). Our survey included 16 female lead households and even though one third of them were members of local farmer's associations, their involvement is likely to be limited. Taboos around what women can and cannot do inhibit female farmers from ploughing their own fields, with or without oxen, and their inclusion in agricultural extension programmes is rare (Pender and Gebremedhin, 2006). Increasing membership to women farmer associations and women only extension programmes will go some way to improving food security for female lead households.

Improvements for female lead households, and poorer households in general, are linked to pressures to sell grain immediately after harvest. As previously mentioned, price of food increases over the course of the year, being lowest just after harvest and steadily increasing until the next harvest (Abebe and Bekele, 2003; Devereux, 2008). Selling grain immediately may solve the issue of on-farm or household storage but then replace it with issues of food insecurity during the lean months leading up to the next harvest (Devereux, 2008; World Bank, 2011). For farmers who do produce surplus grains, but are unable to store it, an alternative to selling it immediately would be utilizing local warehouse receipt systems (Abebe and Bekele, 2003). Where they exist, warehouse receipt systems allow grain farmers to store surplus grain at a centralized warehouse until they need their grain for sales or consumption. Using warehouse receipt systems has the potential to even out grain prices across the year, levelling out grain prices, improving livelihoods and food security on average and providing farmers access to these systems (Abebe and Bekele, 2003; World Bank, 2011).

Metal silos are highly effective at storing grains, beans and cowpeas (Costa, 2014), but the high upfront price is prohibitive for smaller producers without subsidies or loan systems (Tefera et al., 2011). The success of metal silos in Kenya, Uganda and Burkina Faso is encouraging, even if initial uptake is slower in sub-Saharan Africa than it was in Latin America (World Bank, 2011). It is noticeable that female farmers in Latin America have experienced increased status and self-esteem with the introduction of metal silos, as they are in charge of the silo's contents (SDC, 2008). Access to credit, extension programmes and membership of farmer associations increased uptake of new maize storage in Mozambique (Cunguara and Darnhofer, 2011). However, female farmers in Kenya were found to be constrained in their ability to take up new technologies such as improved storage due to poor access to credit (Ndiritu et al., 2014).

An initial assessment of the use of PICS bags found them to be cost-effective for maize producers in Kenya, Ghana, Tanzania, Malawi and Mozambique, especially if used for more than one season (Jones et al., 2011). Ibro et al. (2014) found that female cowpea farmers in Niger, Nigeria and Bukina Faso were more likely to use PICS if they received training and the bags were locally available. If PICS bags are made available to Ethiopian wheat farmers and proper training is provided, they may be a cost-effective and viable means of wheat storage for female and poorer wheat growers. It is important to note, in this respect, that technology targeting one aspect can create new issues in another area because increased efficiencies in one area might increase the workload further along the post-harvest chain, placing some household members at a disadvantage (Beuchelt and Badstue, 2013)

9 Conclusion

Food security in Ethiopia is an increasingly important issue and reducing post-harvest losses is vital to increasing the nation's food security. Saying that post-harvest losses need to be reduced is easy enough, but actually reducing the losses and improving food security is proving to be a challenge. It is not impossible, but there is also no 'one-size-fits-all' solution.

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11 Where to look for further information

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