POST-HARVEST FOOD LOSSES ESTIMATION- DEVELOPMENT OF CONSISTENT METHODOLOGY

INTRODUCTION

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Current world population is expected to reach 10.5 billion by 2050 (UN March, 2013), further adding to global food security concerns. This increase translates into 33% more human mouths to feed, with the greatest demand growth in the poor communities of the world. According to Alexandratos and Bruinsma (2012), food supplies would need to increase by 60% (estimated at 2005 food production levels) in order to meet the food demand in 2050. Food availability and accessibility can be increased by increasing production, improving distribution, and reducing the losses. Thus, reduction of post-harvest food losses is a critical component of ensuring future global food security.

Food and Agriculture Organization of U.N. predicts that about 1.3 billion tons of food are globally wasted or lost per year (Gustavasson, et al. 2011). Reduction in these losses would increase the amount of food available for human consumption and enhance global food security, a growing concern with rising food prices due to growing consumer demand, increasing demand for biofuel and other industrial uses, and increased weather variability (Mundial, 2008; Trostle, 2010). A reduction in food also improves food security by increasing the real income for all the consumers (World Bank, 2011). In addition, crop production contributes significant proportion of typical incomes in certain regions of the world (70 percent in Sub-Saharan Africa) and reducing food loss can directly increase the real incomes of the producers (World Bank, 2011).

Over the past decades, significant focus and resources have been allocated to increase food production. For example, 95% of the research investments during the past 30 years were reported to have focused on increasing productivity and only 5% directed towards reducing losses (Kader 2005; Kader and Roller 2004; WFLO 2010). Increasing agricultural productivity is critical for ensuring global food security, but this may not be sufficient. Food production is currently being challenged by limited land, water and increased weather variability due to climate change. To sustainably achieve the goals of food security, food availability needs to be also increased through reductions in the post-harvest process at farm, retail and consumer levels.

Food losses do not merely reduce food available for human consumption but also cause negative externalities to society through costs of waste management, greenhouse gas production, and loss of scarce resources used in their production. Food loss is estimated to be equivalent to 6-10 percent of human-generated greenhouse gas emissions (Gustavasson, et al. 2011; Vermeulen, et al. 2012). A significant contributor of this problem is through methane gas generation in landfills where food waste decomposes anaerobically (Buzby and Hyman, 2012). The US Environmental Protection Agency reports that in the United States about 31 million MT of food waste accounted for 14% of the 2008 solid waste produced in the country (EPA, 2011) costs roughly 1.3 billion dollars to landfill (Schwab, 2010; Buzby and Hyman, 2012). This is cost to the society through utilities bills and taxes.

A study by Institute of Mechanical Engineers indicates that that current agricultural practices use 4.9 Gha (global hectares or 4931 million hectares) of the total 14.8 Gha (14894 million hectares) of land surface on the earth (Fox and Fimeche, 2013). Agricultural production in addition uses 2.5 trillion m^3 of water per year and over 3% of the total global energy consumption (Fox and Fimeche, 2013). With estimated food losses of about 30-50 % of total production, this translates to wasting 1.47-1.96 Gha of arable land, 0.75-1.25 trillion m^3 of water and 1% to 1.5% of global energy (Fox and Fimeche, 2013).

Given the significant role food loss reductions could have toward sustainably contributing to global food security, it is important to have reliable measures of these losses. Unfortunately, most of the available postharvest loss and food waste estimates are based on the anecdotal stories with few actual measured or estimated numbers. Moreover these numbers, in turn, feed into estimates of food availability which are widely used in food security assessments and policy analyses. For example, FAO's Food Balance Sheet provides data for most food security and consumption analyses across the world (http://faostat.fao.org/site/354/default.aspx) and presents a comprehensive picture of a country's food supply during a specified reference period. Food supply available for human consumption is obtained by deducting from total supplies the quantities exported, fed to livestock, used for seed, and losses during storage and transportation. The food loss estimate in the Balance Sheet is currently calculated using an ad hoc methodology. A robust accounting of food losses which is updated regularly will improve the overall data in the Food Balance Sheet and provide more reliable information for analyses and policy making.

In light of this need, this paper illustrates a conceptual model which will support the development of a template for estimating the post-harvest losses in different staple crops. This paper is divided into four main sections- the first section defines food loss and food waste, the second section discusses the factors responsible for the current food loss situation in different parts of world, and the third section talks about measurement problems, and existing methodologies. The final section of this paper proposes a conceptual model that aims at strengthening future PHL estimates.

FOOD LOSSES AND FOOD WASTE

Post-harvest Food Loss (PHL) is defined as measurable qualitative and quantitative food loss along the supply chain, starting at the time of harvest till its consumption or other end uses (De Lucia and Assennato,1994; Hodges, Buzby and Bennett, 2011). PHLs can occur either due to food waste or due to inadvertent losses along the way. Thus, *food waste* is the loss of edible food due to human action or inaction such as throwing away wilted produce, not consuming available food before its expiry date, or taking serving sizes beyond's one's ability to consume. *Food loss* on the other hand, is the inadvertent loss in food quantity because of infrastructure and management limitations of a given food value chain. Food losses can either be the result of a direct quantitative loss or arise indirectly due to qualitative loss. Food loss and food waste add to contribute to post-harvest food losses as presented in Figure 1.

Food losses can be quantitative as measured by decreased weight or volume, or can be *qualitative*, such as reduced nutrient value and unwanted changes to taste, color, texture, or cosmetic features of food (Buzby and Hyman, 2012). Quantitative food loss can be defined as reduction in weight of edible grain or food available for human consumption. The quantitative loss is caused by the reduction in weight due to factors such as spillage, consumption by pest and also due to physical changes in temperature, moisture content and chemical changes (FAO, 1980). This definition is unsatisfactory since food grains undergo reduction in weight due to drying, a necessary postharvest process for all grains (FAO, 1980). Although this process involves considerable reduction in weight, there is no loss of food value, and therefore, should not be counted as loss. Therefore our analysis will only consider quantitative losses due to spillage and other unintended losses along the supply chain rather than intentional weight loss through drying or other processing.

The *qualitative loss* can occur due to incidence of insect pest, mites, rodents and birds, or from handling, physical changes or chemical changes in fat, carbohydrates and protein, and by contamination of mycotoxins, pesticide residues, insect fragments, or excreta of rodents and birds and their dead bodies. When this qualitative deterioration makes food unfit for human consumption and is rejected, this contributes to food loss.

Food waste, as earlier mentioned, is a subset or sub-category of the food losses (Buzby, and Hyman, 2012). According to Buzby and Hyman, Bloom (2010), food waste occurs when the an edible food item goes unutilized as a result of human action or inaction and is often the result of a decision made farm-to-fork by businesses, governments, and farmers (Buzby and Hyman, 2012). The definitions of food waste and food losses are not consistent worldwide. For e.g., Buzby, and Hyman, 2012, report that Dutch Ministry of Economic Affairs, Agriculture, and Innovation defines food waste to include quality considerations and residual and waste flows in addition to the food loss (Waarts et al., 2011). Wastes & Resources Action Programme (WRAP) final report in 2009 defines waste as 'any substance or object which the holder discards or intends or is required to discard' (Quested and Johnson, 2009). Different studies use appropriate definitions for their needs.

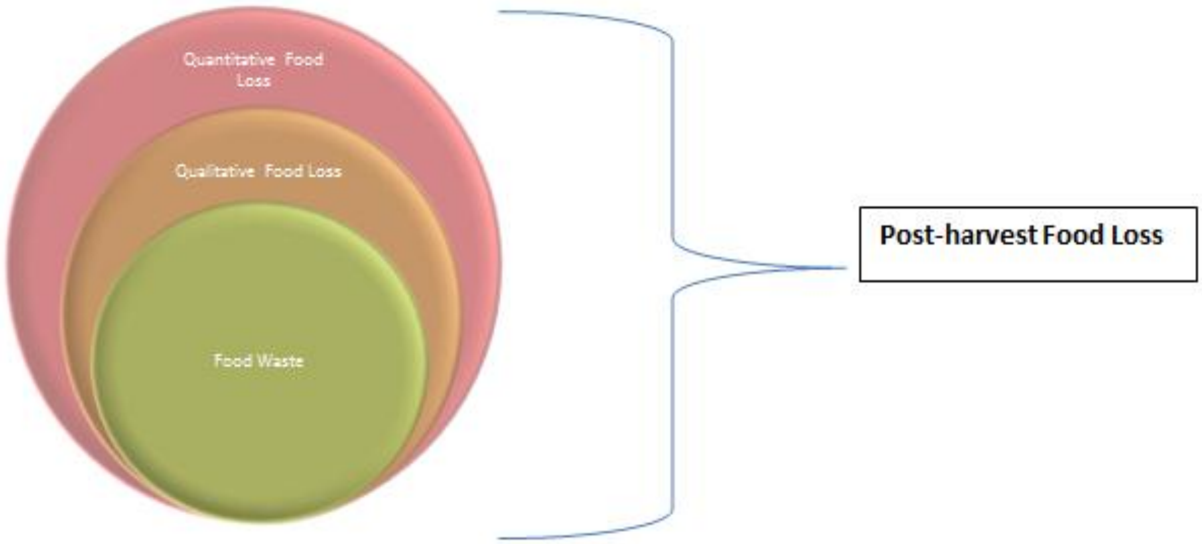


Fig. 1. Post-harvest food loss components.

FACTORS CONTRIBUTING TO TOTAL FOOD LOSS

Factors that contribute to food loss range from mechanization of practices such as harvesting to handling, processing and others, to weather conditions, production practices, management decisions, transportation facilities, grading issues, infrastructure, consumer preferences/attitudes, and availability of financial markets. A typical post-harvest chain comprises of a number of stages for the movement of harvested output from the field to the final retail market. The losses incurred at each step vary depending upon the organization and technologies used in the food supply chain. For example, in less developed countries where the supply chain is less mechanized, larger losses are incurred during drying, storage, processing and in transportation (Fig. 2).

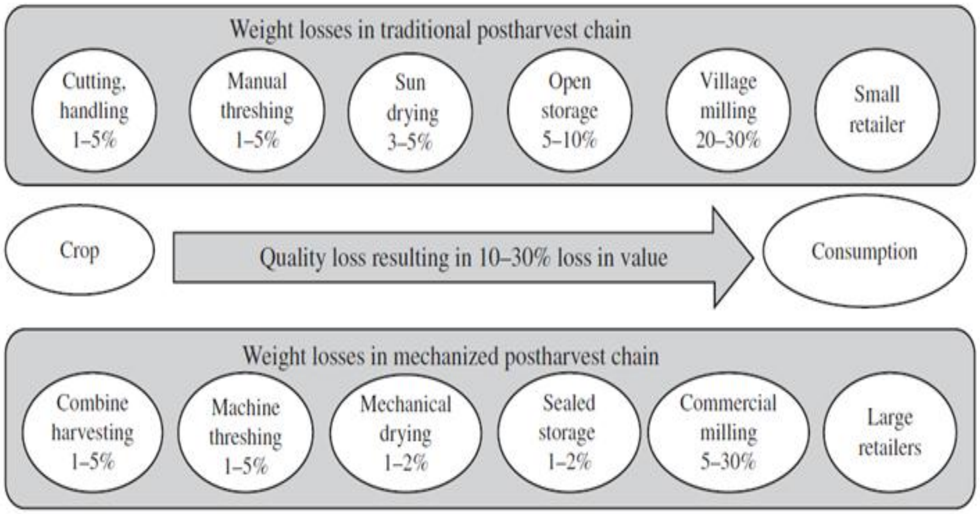
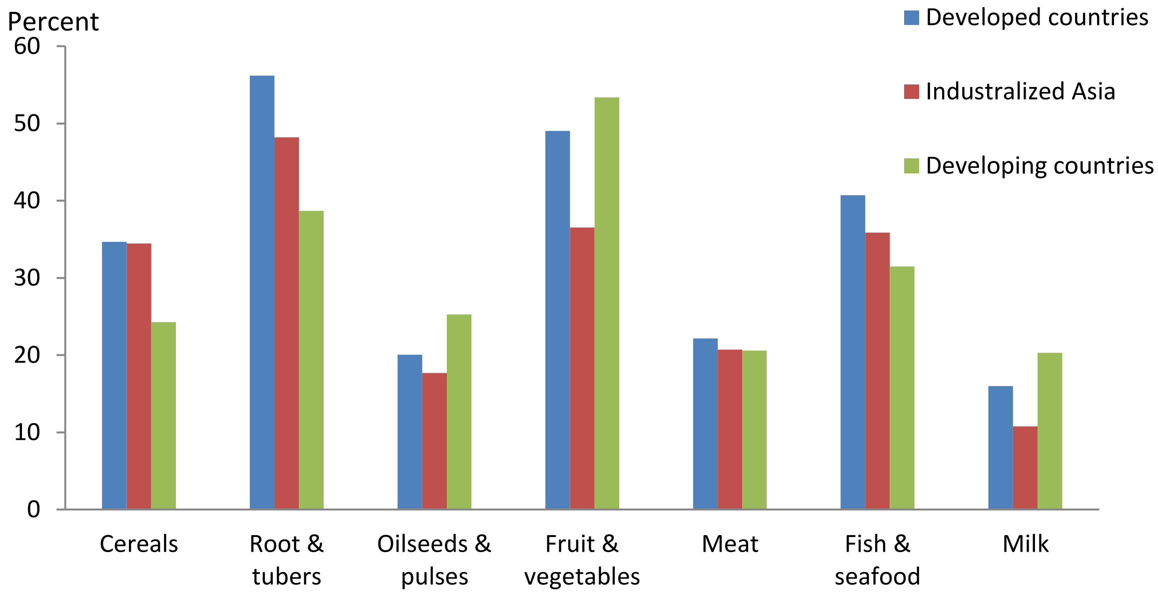


Fig. 2. Traditional versus mechanized postharvest chain (Hodges, Buzby, and Bennett, 2011).

The magnitude and pattern of post-harvest losses (PHLs) therefore vary across countries based on their stage of economic development. In high- and middle-income countries, significant losses occur in the early stages of the food supply chains and at the consumer level (United Nations, 2011). Field losses at early stages may reflect economic decision by the farmer to forgo harvesting due to market conditions or grading perfections demanded by the consumers. Minor losses may also occur at other stages of the supply chain. Food losses are relatively high across many commodities for the developed countries (Figure 3). This could be a reflection that food wastes at the consumer level tend to predominate food losses in the developed countries. Key factors which are responsible for the food waste in the developed countries are growing consumer intolerance of substandard foods or cosmetic defects such as blemishes and misshapen produce, as well as consumer purchases of more food than they consume.

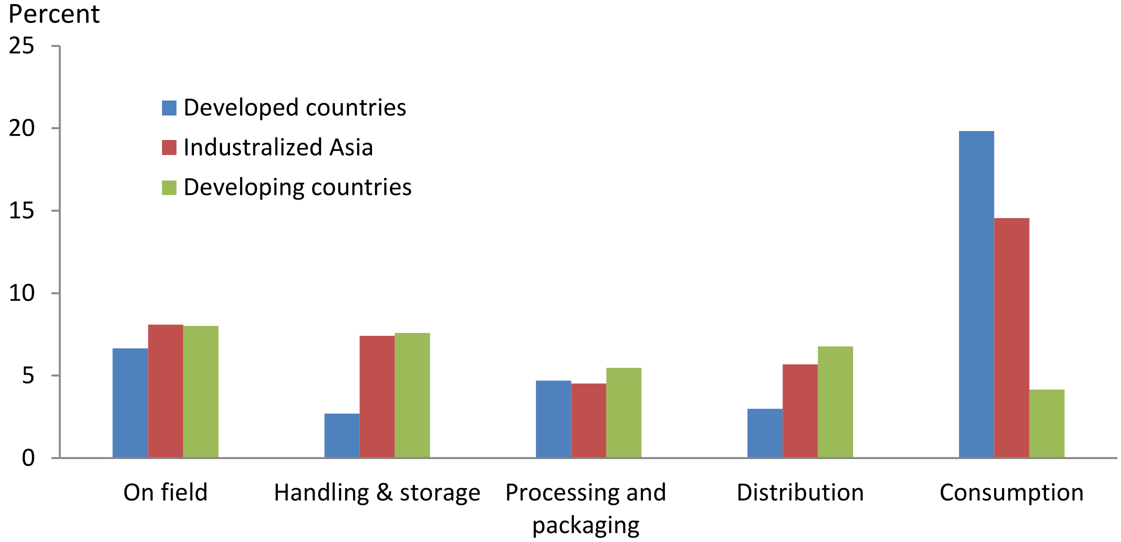


Source: Author calculations using loss parameters from Gustavsson et al. (2011) and 2009 production data from the FAO.
Note: Bars denote percent of production lost for respective commodity.

Fig. 3. Food losses vary by commodity across countries.

Food losses in the developed countries are generally low in the middle stages of the supply chain. This can be attributed to more-efficient farming systems, better transport, better management, storage, and processing facilities which ensure that a larger proportion of harvested output is delivered to the markets (Hodges, Buzby and Bennett, 2011). The extensive and effective cold chain systems, prevalent in these countries, also help to prolong the shelf-life of food products.

In contrast, food losses in the low-income countries mainly occur in the early and middle stages of the food supply chains with proportionally less amounts wasted at the consumer level. Food losses in these countries are the result of "inadvertent losses" due to the 'poor' state of their supply chains (Figure 4). Premature harvesting, poor storage facilities, lack of infrastructure, lack of processing facilities, and inadequate market facilities are the main reasons for high food losses along the entire Food Supply Chain (FSC).



Source: Author calculations using loss parameters from Gustavsson et al. (2011) and 2009 production data from the FAO.
Note: Bars denote percent of supply at each stage which is lost.

Fig. 4. Food losses vary by the stage of supply chain across countries

Loss variations among different country groups can be attributed to the changing food demand patterns at different income levels. Increases in per capita income levels of households across the world are contributing to major changes in food demand patterns (Regmi, et al. 2001). As consumers become wealthier, they tend to demand special 'quality attributes' in the food they consume. In response to these demands, food suppliers have implemented stringent quality standard and certification programs. Products unable to satisfy these standards, even if nutritious and safe for human consumption, become discarded - contributing to food losses. Furthermore as food comprises a small share of the budget for consumers in developed countries do not have a strong incentive to avoid wasting food. In contrast, as food is a large share of the household budget for consumers in low- income countries, purchase behaviors tend to be more frugal - contributing to less waste.

With significant wastage across all food types, per capita food loss in Europe and North America was reported to be high at about 95-115 kg/year, whereas in Sub-Saharan and South-East Asia is much lower at about 6-11 kg/year (FAO, 2011). It is estimated that about1.6 million tons of food are wasted in the United Kingdom because they do not meet the retailer standards (FAO 2013). In addition, UK households are estimated to waste another 6.7 million tons of food each year. Similarly food losses are high in other developed countries with estimates indicating that about 30 percent of all food produced in the United States is wasted (FAO, 2013).

Although waste accounts for a very small portion of the total loss, food loss is significant in the developing countries. Total food losses in Sub-Saharan Africa are estimated to be worth $4 billion per year, an amount which can feed 48 million people (FAO, 2013). Losses on cereals are estimated to be high and account for about 25% of the total crop harvested. These losses can be even greater in perishable products, and account for as high as 50% of harvested fruits, vegetables and root crops (Voices Newsletter 2006).

MEASURING FOOD LOSSES

Consistent measurement of food losses is a necessary first step toward reaching the goal of reducing PHLs. Not much progress has been made in this direction due to 'measurement problems'. Currently there is no single definition of food losses. Nor are there any agreed upon methodologies for consistent measurement of these losses. Problem arises in uniformity in measurement of losses due to differences in social, economic, environmental and political differences among different regions of the world. For example, particular types of damage to grain might result in rejection in one country while such grain might be used for human consumption in another.

In the United States uses a method of calculating the waste generated at different steps in the post agricultural production stages to generate the US Loss-Adjusted Food Availability data. This program was initiated in 1970 by USDA to report food wastes. Food Availability data is available from 1909 onwards but due to constraints regarding factors which go into calculation, the loss-adjusted availability data is available only for the later part of the century. ERS's Loss-Adjusted Food Availability (LAFA) data is a standard proxy for food consumption as it provides the estimates of amount of food available for human consumption after adjusting for food spoilage and other losses (ERS, 2011, Buzby and Hyman, 2012).

Per capita food availability numbers are used for the calculation of the LAFA data. Total food supply is adjusted to incorporate exports, imports and stocks, providing total food availability data. Using population data from the US census, per capita food availability is calculated. This food availability data is then adjusted to account for three loss factors. The first includes losses at the primary production level, i.e. from farm-to-retail level. The next is losses at the retail level such as in supermarkets, hypermarkets, and other retail outlets including convenience stores and mom-and-pop grocery stores. Losses in restaurants and other foodservice outlets are not incorporated. Finally losses at the consumer level are taken into consideration. These include losses for food consumed at home and away from home by consumers and foodservice establishments.

Food losses at the consumer level can arise because of "nonedible share" of a food, such as asparagus stalk or apple core. These data are obtained from the National Nutrient Database for Standard Reference, compiled by USDA's Agricultural Research Service (ARS, 2008; Buzby and Hyman, 2012). Food loss can be the result of plate waste from the edible share such as loss while cooking or loss from uneaten food.

FAO's Food Balance Sheet data calculates per capita food availability for all countries for which they have data based on a methodology similar to USDA's. To obtain food availability, postharvest losses, feed, and food destined for industrial uses are deducted from total food supply, which includes production adjusted for net trade and stocks. FAO's estimates of postharvest losses which enter food availability calculation, unfortunately, are not based on a robust methodology. Development of a consistent methodology to estimate postharvest losses will greatly benefit FAO's efforts in this area.

Another issue to consider in determining a consistent methodology for measuring and estimating postharvest losses is the role of food processing. Processing can lead to a reduction in food weight; however, this loss is not automatically a postharvest loss. In processing, a part of grain is transformed to a by-product, for e.g. in the case of rice and wheat milling a part of the grain is lost with the separation of the bran. But this bran may be fed to livestock and thus is usually utilized elsewhere in the food industry. Similarly, broken grains maybe sold in the market place, but at cheaper rates. Thus, they are not direct food loss since they have alternative uses, often at lower prices (FAO, 1980). Hence it is important to clearly define how postharvest food losses will measured, and to the extent possible, make this definition be globally consistent.

PROPOSED STUDY TO ESTIMATE POSTHARVEST LOSSES

The objective of this study is to develop a consistent and comprehensive framework for estimating PHL. Using this framework, a second phase of the research project will develop econometric models with partners and collaborators to estimate PHLs for selected countries and commodities. The ultimate goal of the project is to improve global food balance sheet data via better estimates of PHLs. Ad hoc methods for calculating PHLs have been used in the past to estimate food availability data. Poor PHL estimates impact the quality of food availability data and other assessments based on that data. For example, food security assessments and other analyses which consider projections of future food needs rely on food balance sheet information. Thus, strengthening of PHLs database will help improve other estimations and projections which rely on food balance sheets.

Review of Existing Methodologies and Gaps

Limited work has been conducted in the estimation of PHLs. Most of the published works available on PHL estimation are FAO initiatives, based on surveys in the developing countries. Other works include estimation methods such as Loss-Adjusted Data in the developed countries with considerable inconsistencies in the entry data, and few independent country and commodity specific studies. In the following section some of these published methodologies and their gaps are discussed. Other important studies are listed in Appendix III of this paper. Some patterns are highlighted towards the end of this section which emerged while reviewing these papers.

In designing studies to estimate PHL, the first challenge is to establish the procedure to accurately measure weight loss which will be used to estimate total PHLs. The conventional method for estimating losses in maize is to take the ratio of weights of discarded cobs over good cobs (Compton, Floyd, Ofosu and Agbo, 1998). This method tends to underestimate the losses as it does not account for partially-filled or partially-damaged cobs. Therefore, Compton et al., 1998, proposed a modified count and weigh method (gravimetric method) to assess weight loss in stored maize cobs (Compton, Floyd, Ofosu and Agbo, 1998). This method has also been widely used by number of other studies done on maize in other parts of the world as listed in Appendix III. Compton and Sherington (1998) further modify this approach to propose a new method to estimate the weight loss due to insect pests in stored maize cobs in Ghana. They highlight that most of the earlier assessment methods are relatively time-consuming and demand specialized staff and equipment. The researchers in this study develop a scale system ranging from 1-6 depending upon the damage to the cobs. Coefficients were established for each damage class using a modification of the count and weight technique (Boxall, 1986; Compton and Sherington, 1998).

For the estimation of the damage class coefficients in equation (1) to be used in this method, samples were obtained from each of these six damage classes. The mean weight loss for each damage class was used as a preliminary estimate of coefficient. Later they were further adjusted after obtaining fit between visible percentage of grain loss (Visloss) and cob weight loss (Wgtloss). Visloss was estimated using visual scale and weigh method and Wgtloss by modified weight and count method, mentioned above. These coefficients were repeatedly adjusted within reasonable ranges to give best visual fit between Visloss and Wgtloss. Then, total loss based on the visual code method was estimated by the equation below.

$$Visloss = \frac{0\%N_1 + 2\%N_2 + 15\%N_3 + 30\%N_4 + 40\%N_5 + 80\%N_6}{N_T} \qquad (1)$$

Where: $N_{1,\ldots,}N_6$ are the number of cobs in classes 1 to 6 in the sample, N_T =total number of cobs in the sample, and Visloss is estimated weight loss.

In the Visloss count method, individuals were assigned to score the cob samples independently into different damage classes depending upon the photographs provided to them. The study calculates the mean bias of visual estimates and the standard error for the estimates of weight loss using visual scale equation. The bias was estimated for each sample within a batch as the difference between predicted value using visual scales (Visloss) and the measured loss using count and weigh method (Wghtloss). Only in one out of the five batches, this bias was significant. However, the magnitude of the bias was very small (0.7%). Overall, post-harvest weight loss estimations in the sample batches of this study conducted for maize in Ghana were in range of 4.8%-21.5%.

Another study conducted in Punjab (India) provides an example of postharvest loss estimation for a perishable product. The study was conducted for kinnow (citrus fruit) using random sampling technique in the largest production region of the state in 2004-05 (Gangwar, Singh and Singh, 2007). After selection of the region, four villages were randomly chosen and the kinnow growers were grouped into three categories depending upon the size of their orchards: (1) less than 2 ha; (ii) 2-5 ha; and (iii) above 5 ha. Data were gathered during the fruit harvesting and marketing seasons through pre-tested questionnaire by personal interview method. Simple averages and percentages were used to calculate the post-harvest losses at different stages identified in the kinnow supply chain.

In the kinnow study, two methods of harvesting were adopted. The first method involves just dropping them on the ground and the second one uses clippers, followed by the collection of fruits in crates or bags. In the first method PHLs at the harvesting level were recorded to be 10.63 % compared to only 2.51 % in the second method. PHLs also varied depending upon the distance to the market. When they are marketed to medium-distance markets, PHLs were 5.15% whereas for long-distance markets they were 8.17 %. Overall losses were 14.47 % for the Delhi market and 21.91% for the Bangalore market.

Basavaraja, Mahajanashetti, and Udagatti (2007) conducted a study to estimate PHLs on cereals in the state of Karnataka (India). The study covered rice and wheat and was designed to identify which stage of the post-harvest is responsible for the greatest loss (Appendix I , Basavaraja, Mahajanashetti and Udagatti, 2007). Survey data was collected from 100 farmers, 20 wholesalers, 20 processors and 20 retailers for the year 2003-04 (Appendix II). Linear regression was used to examine the role of different factors affecting post-harvest losses in the rice supply chain from the field to processors and sellers. The storage stage was identified as contributing to the highest percentage weight losses along the entire supply chain. Losses at the farm level were estimated at 3.82% for rice and 3.28% for wheat. Education level of farmers and weather conditions also had significant impact on post-harvest losses.

The review of these past studies provides evidence that the measurement of post-harvest losses (PHLs) can be time and labor consuming. There is not one practical option which can be adopted to obtain more accurate measures of PHLs. Instead similar but improved experimental studies could be used where the measured losses can then be regressed on a number of factors to obtain parameters which can later be used for predicting losses. The idea behind this is to use factors whose values are readily available or easily computable, such as preexisting indices which denote the quality of supply chain, agro-climatic zone and other factors.

The second observation made while reviewing these studies is that the nature and incidence of losses can significantly vary across commodities, particularly when comparing perishables and non-perishables. For example, for similar farm, harvest and marketing situations, packaged grains and citrus will likely incur different levels of losses during transportation. Therefore distance to market may not be of importance to grains, but it becomes very important to perishables in the developing countries.

Finally, as implied by the second observation, the critical stage in the supply chain where the greatest magnitude of PHLs occurs differs across countries and commodities. In the Punjab citrus case, two stages appear to be critical, harvesting and transportation. Significant losses could be prevented by using harvesting techniques which prevent damage to the fruit. Similarly, losses could also be minimized by either reducing the distance to markets, or likely by using climate-controlled transportation with proper packaging of fruit. On the other hand, the Karnataka study indicated that for cereals such as rice and wheat, 75% of the total PHLs occur at farm level and 25 % at market level. Storage (33-35%) was the biggest contributor of these losses along the entire supply chain.

Given the nature of PHLs, studies to date have not followed a consistent methodology. There are a number of inconsistencies which exist among these studies which make the comparisons among the measured estimates doubtful. The first inconsistency is that they report the percentage loss of weight of either the sample or the total production. (For e.g. Damage by mold may be localized to one part of the storage space. If the experimental sample is obtained from that section the extrapolations of the sample loss to the overall production will provide an inflated measure. This leads to unreliable measures and disparity in reporting the common denominator for comparison.

The second inconsistency arises from the fact that they do not follow a holistic approach to measurement of PHLs. Most of the studies in the last three decades as shown in Figure 6 have focused only on the storage stage of the supply chain, ignoring the other important steps which also contribute to PHLs. Important stages which contribute to overall PHLs are listed on the left hand side of Figure 6. This represents a gap in the estimation procedure which needs to be addressed for more reliable future estimates. Figure 7 presents the various steps a commodity goes through depending upon the food groups to which it belongs (eggs don’t pass through as many hands as the cereal does in post-harvest value chain). The stages and length of value chain depend on the perishability and physical properties of a crop. The third inconsistency comes from the fact that only a few crops have been studied through the loss measurement lens. Maize and sorghum have been the focus for most of the experimental studies (Figure 6 literature review summary). The need for such a focus is often justified by the importance of maize as a staple crop of developing regions of the world.

Efforts to estimate post-harvest losses have therefore been hindered by the dearth of reliable parameters for estimation. To date, no single and consistent framework exists which is used in the estimation of PHLs. African Postharvest Losses Information System or APHLIS is an attempt to address this need for a consistent estimation framework. It has a regional focus and is designed to compute quantitative postharvest losses for cereals under different farming and environmental conditions in East and Southern Africa. APHLIS is backed up by a database and a postharvest loss calculator which together facilitate the estimation of annual postharvest losses (by province) for the cereal grains of the countries of East and Southern Africa.

For calculating the losses, APHLIS divides the African region into 5 broad climatic zones based on the Koppen Climatic code (Peel, Finlayson and McMahon, 2007). These are the tropical savannah, semi-arid, temperate dry winter hot summer, temperate dry winter summer, and desert. These zones are assigned numbers and corresponding parameters for estimation purposes. The framework focuses mainly on large grain borer damage and on 7 cereal crops, maize, rice, sorghum, millet, wheat, barley, and teff. The calculator incorporates grain losses at different stages of the supply chain in its estimation. The stages included are 1) harvesting and drying, 2) threshing and shelling, 3) winnowing, and 4) transportation. The inputs required for the loss estimations by this system requires entries on production quantity (tons), marketed percentage, rain at harvest (0 or 1), storage duration (months), and incidence of large grain borer infestation (0 or 1), The default parameters are then used to predict the losses for that season and crop.

These default loss parameters set in the online calculator are obtained from published work or surveys conducted in the region. When a crop is harvested multiple times within a year (three seasons), the associated losses are estimated to be higher. Hence, the final percentage loss is computed as a weighted average. Similarly, farmer or farm characteristics and decisions regarding marketing and storage, as well as weather conditions affect the parameters considered for PHL estimation in the calculator. The calculator then provides a loss estimate associated with a given proportion of borer infested grain at harvest.

Figure 5 shows an example of the maps which are generated using this application. The maps give an overall regional dispersion of losses. The legend in figure 5 provides the extent of damage by larger grain borer (LGB). No information is available for yellow regions of the maps (Figure 5). The changes of these maps over the years can be essential input to see the impact of new policies or innovations in highly affected regions. The detailed description of APHLIS is provided in the text box.

APHLIS provides a valuable framework for estimating PHLs in south and east Africa. However, it has its limitations. The parameters used in the online calculator are often old or based on studies conducted in other parts of the world. Moreover, the framework is mainly restricted to the large grain borer infestation and to seven major crops. The framework does not include losses from processing (e.g. milling) or from quality changes. Rembold et al. (2011) also report some limitations to the calculator which need to be addressed to improve its accuracy. They propose generating more loss data at various stages along the post-harvest chain, expansion of the calculator to cover other crops, incorporating climate variability in forecasting losses, and better coordination with other PHL estimation systems and projects.

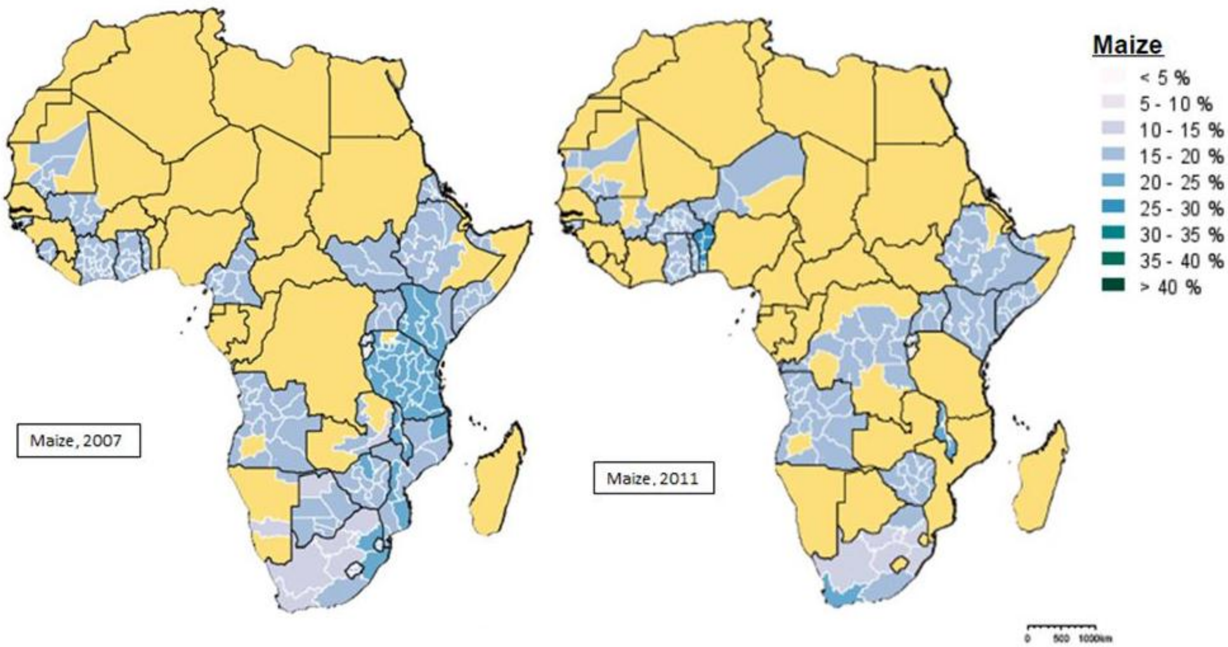


Fig. 5. Estimated % cumulative post-harvest weight loss of maize in year 2007 followed by year 2011 by countries (APHLIS, http://www.aphlis.net)

Loss-numbers in APHLIS are adjusted or shifted by observations made by the local experts depending upon the following factors:-

1. Production-affects the loss calculation. This means when there is more than one harvest for a crop higher are the loss numbers computed as weighted average.
2. Marketed at harvest- affects the proportion of harvest at which storage losses are considered. Moreover, it is assumed that subsistence farmers eventually consume all grain and don't market which further reduces their transport to market or trader store losses
3. Rain at harvest- affects the % of harvesting loss. If there is rain the default value set is 16.3%.
4. Storage duration- more duration higher the loss for three months. It is assumed to be zero for first 3 months, for 4-6 months % storage figure is divided by 2 (i.e. is only half of the annual figure.).
5. LGB-for maize if they are discovered, the storage losses are automatically

After entering all the required information in APHLIS, it produces loss estimates of African regions for a particular

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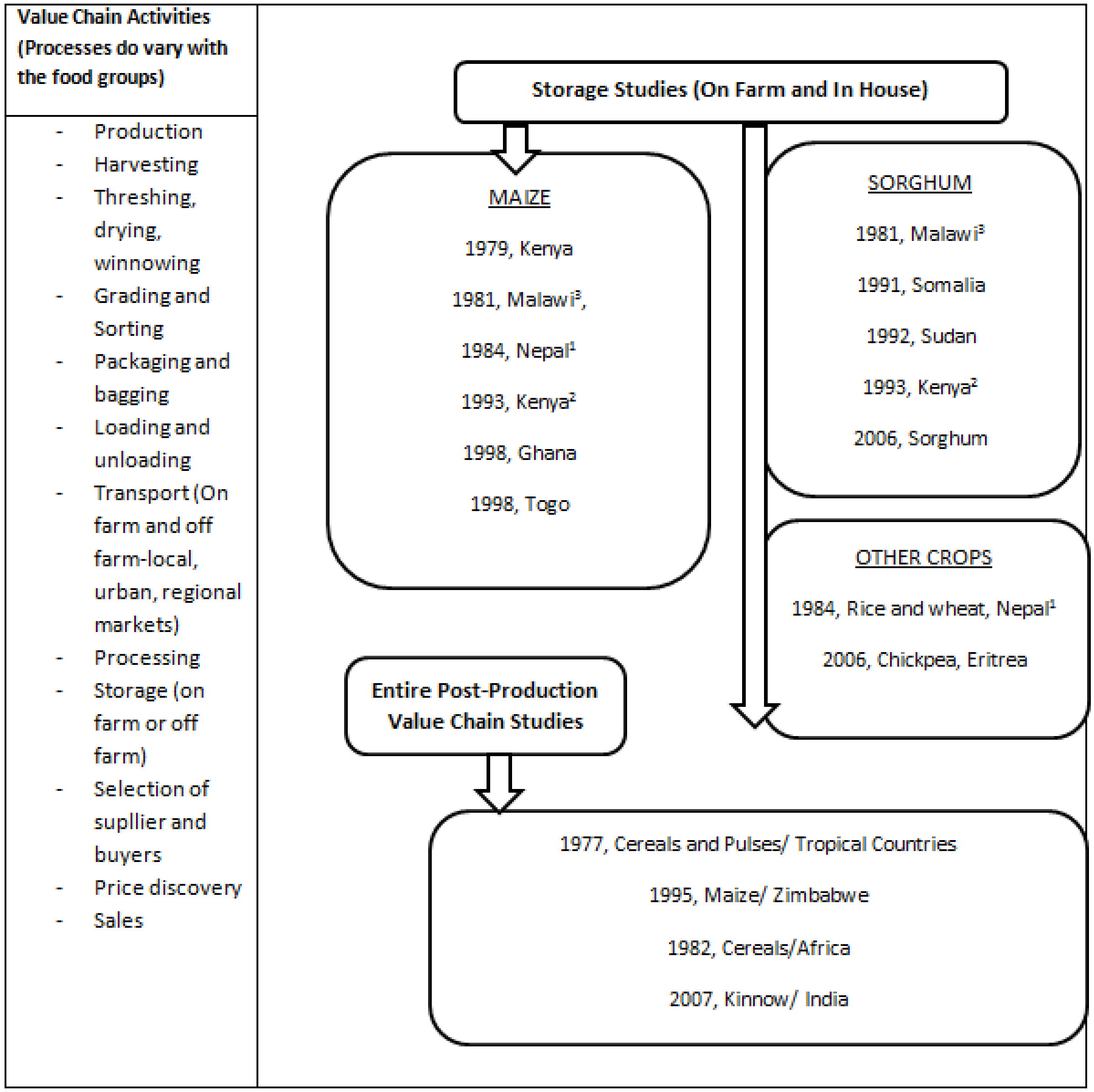

Figure 6. Chronological depiction of experimental studies reviewed in this paper

VALUE CHAIN	Production	Harvesting	Threshing	Drying	Winnowing	Grading /Sorting	Packaging	Loading/Unloading	Transport	Processing	Storage	Selection of Supplier and buyers	Sales
FOOD GROUPS													
Cereals	X	X	X	X	X		X	X	X	X	X	X	X
Roots and Tubers	X	X		X		X	X	X	X	X	X		X
Fresh Fruits	X	X				X	X	X	X	X			X
Meat	X	Slaughtering				X	X	X	X	X			X
Milk	X	Milking					X	X	X	X			X
Pulses and Oilseeds	X	X	X	X	X		X	X	X	X	X	X	X
Fish	X	Fishing		X			X	X	X	X			X
Eggs	X	Collection				X	X	X	X	X			X

(green)	High Probaility to go through this process
(yellow)	Medium Probability
(pink)	Low Probability

Note: This table uses the food groups of FAO and the knowledge of the authors. The production process is not included in discussions for the sole purposes of this paper.

Figure 7. Different food groups go through different processes in value chains.

A few of the studies conducted as a result of the 1970's Food crisis and FAO summit are reexamined in this paper. Some these studies were discussed earlier in this paper. In addition, a summary of the patterns that emerged from the studies is summarized in Appendix III. While storage is the main focus of most of the studies the paper by Adam (1977) identified a gap that exists in the estimation procedure. The effects of insects and rodents in maize were examined by De Lima (1979). Golob (1989) highlights the fact that high yielding varieties of maize and sorghum were more susceptible to infestation

Schulten (1982) provided a second review of the literature on the post-harvest loss estimations. He noted that, in 1980s, 25 of the post-harvest studies on maize were undertaken in tropical Africa while also noting that cowpeas showed large storage losses. In the mid 1980's an experimental study was done in Nepal to evaluate the extent of post-harvest loss occurring in the storage of staple crops (maize, wheat, rice) with a focus on the insects responsible for the maximum loss (Boxall and Gillett, 1982). Post-harvest loss estimates in this study were only 5% in maize compared to ealier reports of 10-30% and were attributed to low yields due to drought.

During the early 1990's, sorghum became the main focus of studies on PHLs. The extent of damage by insects and rodents was measured for sorghum in Somalia and Sudan (Lavigne, R. J. 1991. and Seifelnasr, Y. E. 1992). The remainder decade showed the focus shifting towards maize again in different parts of Africa. Later on there were attempts made to modify the 'weight and count method (gravimetric method)' of PHLs measurement into different kinds of estimation techniques such as'modified weigh and count method' and 'visual loss estimation methods' to overcome some limitations posed by earlier measurement techniques (Mvumi, Giga and Chiuswa,1995; Compton, Floyd, Ofosu and Agbo, 1998; Compton and Sherington, 1999; Pantenius, 1998).

By the 2000s, estimation methods started to take a more holistic approach by incorporating more value-chain steps, since any stage can act as a food loss point (FLP). Since storage has been the main target as mentioned a number of times, some studies were later undertaken to measure the impact of various kinds of insect treatments at the storage stage (Haile, 2006). There were attempts made to estimate the PHLs in the entire value chain of the commodity studied, for (e.g. Kinnow and Rice/Wheat in India) (Gangwar and Singh, 2007 and Basavaraja, Mahajanashetti and Udagatti, 2007). Authors using a more holistic measurement approach found the added advantage of identifying the stage contributing the most to the PHL damage.

Framework for estimating post-harvest food losses

For the development of a consistent methodology for the assessment of post-harvest losses of food commodities, it is necessary understand the concepts of loss. There is wide range of variations adopted by researches. This can be attributed to the complexity and variability of all the post-harvest operations involved in the movement of food from harvest to fork. For the purpose of this paper definitions provided in second section will be adopted for further analysis. The best way to understand the theoretical or conceptual model is to understand steps which comprise of the post-harvest operations.

Food travels along the value chain from harvesting to consumption. Losses occur at each stage along the chain and contribute to total PHL. The loss at each stage is driven by different factors, examples of which are described in Figure 8. The relative importance of a particular stage or factor toward contributing to total PHL will vary across countries and commodities. For example, estimating losses for a sophisticated, vertically integrated chain will likely require consideration of fewer factors than for a less integrated chain where the commodity undergoes several transactions before reaching the retail outlet. Therefore while the conceptual framework is the same across all countries and commodities, the actual econometric model used for PHL will vary across countries and commodities. Our future econometric analysis will exclude losses during the consumption stage of the value chain.

Food leaves the field by the process of harvesting, where mature crops are gathered from the fields. Harvesting methods can vary from most-labor intensive on small farms to most expensive and sophisticated farm machinery, like the combine harvester. There are also other external factors which affect the amount and quality of food harvested from the field. On a broad base, food products can be divided into two main categories- perishable and non-perishable. Perishable commodities comprise of food products which last only for short periods of time such as a few days to weeks. e.g. - milk, meat, fish, fruits, tuber and vegetables etc. On the other hand non-perishables have longer shelf life lasting from months to years, for e.g. cereals, rice, lentils, and dried fruits. Different food groups vary in the way they are harvested from the field. For perishable food groups the process consists of plucking and storing in boxes or bags but in case of non-perishables such as cereals additional steps such as threshing and cleaning are required.

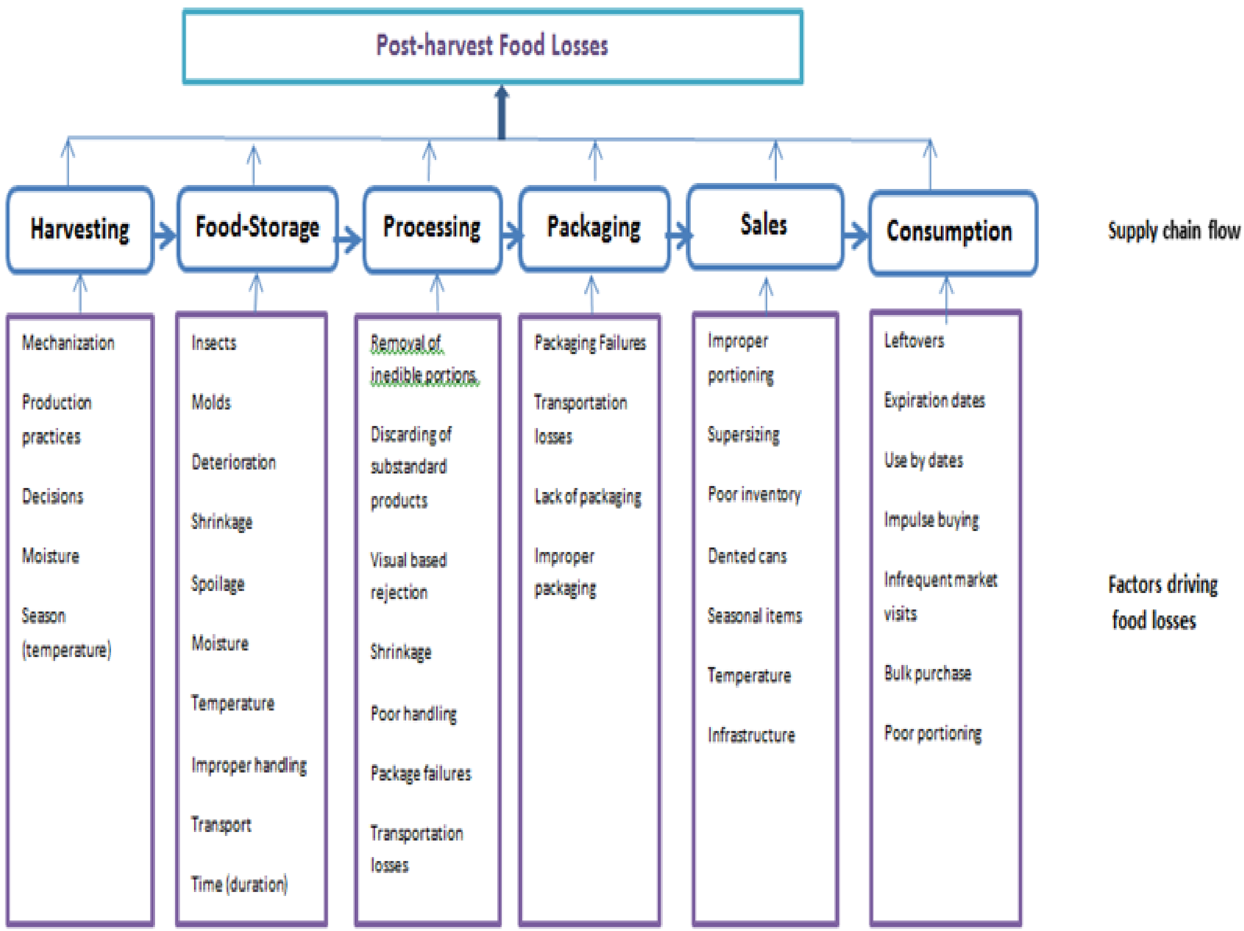

Figure 8. Conceptual model in post-harvest Loss Estimation

Threshing is done either by traditional or modern method, depending upon the resources of a country or a farm. Threshing is followed by winnowing or cleaning. It is method developed over the centuries which is used to separate grain from the chaff. It is also used to remove insects, weevils, debris or other pests form the stored grains. The coarser sediments from the grain can be removed by wind or flowing water forces. Grading is the next step in harvesting, which is used for both perishables and non-perishables. In less developed markets, market is generally not differentiated by grades and quality which tends to lower the profit margins for farmers. But in highly developed supply chains, grading is an important step in the post-harvest process.

The quality of technology used and labor availability have major impact on PHLs. Weather and temperature fluctuations can have significant impacts on food losses, but mechanization and climate-control technologies can reduce these losses. Mechanization of the harvesting and food procurement process can improve efficiency, reducing losses. Precision agriculture in developed countries has been an important revolution for making agriculture production system more efficient in terms of production and harvesting.

Drying is the second important component of the post-harvest food chain (PHFC). Drying is also a method of food preservation which works by removing water from the food. This method has been used since centuries to preserve food. A solar or electric food dehydrator can greatly speed the drying process. Air drying, sun drying, smoking or winds drying are few methods that are employed to evaporate water from cereals. Drying effectively prevents the growth of bacteria, yeasts and molds in the food. For non-perishable, however, it is an important activity before they can be moved to storage.

As indicated earlier in literature review, transport conditions and transport distance play an important role in influencing the magnitude of PHLs. Larger distance, bad modes of transport and outdated use of storage containers lead to higher PHLs. Furthermore, storage conditions such as temperature, moisture, technology, container material and buildings contribute greatly to losses incurred at this stage. High moisture and temperature provide favorable environment for pest and mold multiplications. They also lead to faster biological deterioration by catalyzing the ripening process. Time of storage duration can give higher chances for these pests to complete their reproductive cycles and multiply. The rate of multiplication of pests and molds depends essentially on the species affecting the product.

Processing of initially stored or fresh food is an essential part to make it marketable and to meet consumer demands. The condition of processing plants play a major role in defining the extent of PHLs. Food losses at processing facilities may occur due to procurement of substandard produce, which not meet the requirement of sales and marketing divisions. These products are then discarded. Visual inspection by workers can also play an important role since the workers may engage in disposing contaminated foods (cereals and meats) or misshapen produce (fruits and vegetable). Sudden shrinkages due to changes in temperature and moisture changes can also lead to discarding some of agriculture products at processing facilities.

Packaging of the processed products is affected by numerous biological and technological factors. Less developed supply chains have poor or no standards for packaging materials resulting in speedy spoilage. The lack of adequate packaging leads to transportation losses while moving this packaged product to the market. Poorly-packaged food lose moisture quickly when exposed to unfavorable conditions, contributing in turn to food losses. These losses can be greater if poor-packaging is accompanied by poor-logistics for marketing. Poor market logistics is a big concern in less developed food supply chains.

To sum up, different factors affect the efficiency of each stage as products move to the next stage in the supply chain. Variations in the optimal conditions result in inadvertent food losses which are higher than the standard conversion factors for food processing. To summarize, three main factors appear to contribute to most losses: technology, weather and infrastructure. Therefore, these factors, along with other site-specific play a significant role in determining food losses from the farm to the retail outlet. This study will exclude food losses at the consumer level.

Table 1. Factors affecting post harvest losses at critical stages of food supply chain.

	Factors affecting postharvest losses (PHL) (Xj)								
Critical stages of food supply chain (Si)	***Moisture***	***Weather***	***Pests/disease***	***Infrastructure***	***Size of operation***	***Level of mechanization***	***Quality of management***	***Operator characteristics***	***Access to capital***
Harvesting	X	X	X		X	X	X	X	X
Food storage	X	X	X	X	X	X	X	X	X
Processing	X	X	X	X	X	X	X	X	X
Packaging				X	X	X	X	X	X
Sales				X	X		X	X	X

Note: Food waste at the consumer-level will not be covered in this study.

For statistical estimation work, the total PHL at any post-harvest stage for a given commodity and region is the sum total of food losses occurring at each of stage of the process (Table 1).

Total PHL = Sum of PHL at each stage of the food supply chain

Total PHL $= \sum S_i = \sum f(X_j)$…………………………………………………………….(3)

Where 'Si' stands for the losses in each critical stage of FSC (Food Supply Chain);'X_j' stands for the factors affecting losses at each step and 'i' represents critical stages from harvesting to sales.

$S_i = \sum f(X_j)$……………………………………………………………………………….(4)

The equation (4) on the right hand side represents post-harvest losses at particular stage in the food supply channel and on the left hand side represents all the measurable factors which contribute to these losses. Food losses at the different stages represented in Figure 6 can further be represented in a functional form as follows.

Losses at harvesting given by,

PHL_{SH} = f (agroclimatic factors, farm and farmer related factors, level of mechanization, and credit availability).

Losses in storage is given by,

PHL_{SS} = f (agroclimatic factors, farm and farmer related factors, length of storage, distance to storage, quality of storage, and credit availability).

Losses during processing given by,

PHL_{SP} = f (agroclimatic factors, processing plant related factors, quality of supply chain, use of standards and grading, and credit availability).

Losses during packaging are given by

PHL_{SPK} = f (agroclimatic factors, firm and operator related factors, quality of packaging, transportation, and credit availability).

Finally losses during sales are given by,

PH_{SQ} = f (agroclimatic factors, retail outlet and manager related factors, quality of logistics and inventory control, and credit availability).

As earlier mentioned, we will be focusing only on the segment of the supply chain which covers harvesting through sales and will exclude food losses at the consumer stage. In the actual equations which will be estimated, we will focus on readily available information which can be used to predict losses. These may include weather and climate data, indicators of agroclimatic zones, appropriate indices to represent the quality of management and the stages of the supply chain. Controlled experimental surveys will be developed to calculate losses at each stage. Different measurable factors which impact the food losses will be explored and indexed where possible. These losses will then be regressed using the different factors as variables. The estimated parameters can be used to project and updating future losses and also to identify which component of the chain needs the greatest attention to minimize losses.

CONCLUSION

This paper has highlighted the importance of reducing postharvest food losses as a necessary step in ensuring future global food security in a sustainable manner. Given the challenges posed by climate change and limited land and water resources, food security cannot be achieved merely through increases in agricultural productivity. Attention also needs to be given to measures to reduce losses along the farm-to-consumer chain. Reduced losses not only reflect an increase in food available for human consumption, but they also reflect a more judicious use of our limited natural resources.

There have been very few past studies conducted to estimate food losses. The existing studies have been mostly one-off and do not adopt any consistent methodologies. While the African Postharvest Losses Information System or APHLIS has recently made an effort to provide a framework to calculate food losses using a common methodology for south and east Africa, the input used in this process is based on work which may be outdated or not directly relevant. Therefore, it is critical that a more broader and updated effort be implemented to improve the ability to estimate postharvest food losses.

The paper outlines a framework which can be adopted for consistent estimation of postharvest losses for different commodities and countries. As a follow-up to this work, using the methodology discussed here, surveys can be designed to conduct field work to estimate losses. Based on the survey data, econometric models can be used for selected commodities and countries to estimate the losses.

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Appendix I

Table 2. Estimated post-harvest losses at different stages in rice and wheat : 2003-04

Stages	Rice		Wheat	
	Loss (kg/q)	Loss (%)	Loss (kg/q)	Loss (%)
I Farm level losses				
• Harvesting	0.40	7.70	0.36	8.33
• Threshing	0.52	10.02	0.44	10.19
• Cleaning/Winnowing	0.20	3.85	0.14	3.24
• Drying	0.80	15.41	0.66	15.28
• Storage	1.20	23.11	0.95	21.99
• Transportation	0.50	9.63	0.51	11.81
• Packaging	0.20	3.85	0.22	5.09
Total losses at farm level	3.82	73.57	3.28	75.93
II Wholesale level losses				
• Storage	0.12	2.31	0.08	1.85
• Transit	0.17	3.27	0.12	2.78
Total losses at wholesale level	0.29	5.59	0.20	4.63
III Processor level losses				
• Storage	0.01	0.17	0.01	0.19
• Transit	0.01	0.15	0.01	0.14
• Grain scattering	0.01	0.10	0.01	0.14
Total losses at processor level	0.03	0.42	0.03	0.46
IV Retailer level losses				
• Storage	0.53	10.21	0.41	9.49
• Transit	0.32	6.16	0.25	5.79
• Handling	0.21	4.04	0.16	3.70
Total losses at retailer level	1.06	20.42	0.82	18.98
Total post-harvest losses	5.19	100.00	4.32	100.00

Source: Basavaraja, H., S. B. Mahajanashetti, and N. C. Udagatti. 2007.

Appendix II

Table 3. Factors affecting post-harvest losses in rice and wheat at farm level

Explanatory variables	Rice		Wheat	
	All	Step-down	All	Step-down
Intercept	4.3794 (0.418)	3.7000 (0.327)	1.3997 (0.884)	1.2021 (0.720)
Age of the respondent (X_1)	-0.1062 (0.064)	-	-0.0130 (0.018)	-
Education of the respondent (X_2)	-0.1277** (0.043)	-0.1311** (0.035)	-0.0652** (0.017)	-0.0663** (0.014)
Total production of the crop (X_3)	0.0187** (0.006)	0.0218** (0.006)	0.0006 (0.008)	-
Area under the crop (X_4)	0.0042* (0.002)	-	-0.0021 (0.008)	-
Area under irrigation (X_5)	0.0040** (0.001)	0.0504** (0.005)	-0.0016 (0.008)	-
Area under commercial crops (X_6)	0.0056** (0.003)	1.3386** (0.245)	3.42E-05 (0.0004)	-
Storage dummy (X_7)	0.0551 (0.157)	-	0.1107** (0.031)	0.1146** (0.026)
Weather dummy (X_8)	0.0940* (0.0309)	0.1885** (0.081)	0.0178 (0.028)	0.1885** (0.081)
Transportation dummy (X_9)	-0.1365 (0.267)	-	0.0003 (0.029)	-
Threshing machine dummy (X_{10})	-0.2420 (0.115)		-0.0085 (0.024)	-
Labour dummy (X_{11})	0.1506 (0.086)	0.2659** (0.080)	-0.0085 (0.024)	-
R^2	0.72**	0.62**	0.76**	0.70**
F-value	9.07	18.30	12.57	14.58
$\bar{R}^2$	0.46	0.34	0.52	0.47

Note : Figures within the parentheses are standard errors of coefficients
** Level of significance p<0.01
* Level of significance p<0.05

Source: Basavaraja, H., S. B. Mahajanashetti, and N. C. Udagatti. 2007.

Appendix III

Authors	Paper	Journal	Commodity/Country	Methods	Findings
Adam, J.M.1977	A review of the literature concerning losses in stored cereals and pulses	Trop. Sci, 19, 1-28.	Cereals and Pulses/Tropical Countries	This paper provides the review of Literature published since 1964.	Large gaps were identified and storage was main focus of most of world studies done until 1964.
De Lima, C.P.F..1979	The assessment of losses due to insects and rodents in maze stored for subsistence in Kenya.	Tropical Stored Products Information, 40, 5-13.	Maize/Kenya	Losses were studied over several years employing appropriate field survey techniques and using area, cluster and line sampling methods. Study was done to estimate losses in maize for subsistence storage due to insects and rodents.	Annual loss in subsistence maize was found 4.54 % percent due to insects and 1.45 % due to rodents.
Golob, P. 1989	A Practical appraisal of on-Farm storage Losses and loss assessment methods In the Shire Valley of Malawi	Tropical Stored Products Information, 40, 5-13.	Maize and Sorghum/ Malawi	Used surveys of farm-level grain storage in Southern Malawi. “Standard Volume Weight (SVW) Method” and “Count and Weigh Method” for calculating loses were employed for estimation.	Considerable likelihood of greater losses with high-yielding varities is indicated. Losses observed in Maize reported to be 3% or less and in Sorghum 2% or less.
Schulten,G.G.M. 1982	Post-harvest losses in tropical Africa and their prevention	Food and Nutrition Bulletin, 4(2), 2-9.	Post-Harvest Losses/Africa	Used a literature review of African studies done on PHLs. In 1980, 25 of these projects were conducted in tropical Africa.	Most projects dealt with maize. Cowpeas showed large storage losses. Survey results show that the weight losses at farm level are less than previously . The maize variety, the storage method, and gradual decrease in the quantity of produce stored have a large impact on the final loss figure. Loss in quality identified to be more important than weight loss.
Boxall,R. A. 1984	Farm level storage Losses in eastern Nepal	Tropical Products Inst.	Maize, Wheat, Paddy/Nepal	Harris and Lindblad (1978) loss assessment methodology was used to estimate losses in three staple crops in Nepal. Study is concentrated on insects which cause major grain loss. Household samples	Maize losses were recorded (5%) considerably low than the previous years recordings (10-30%). This was attributed to low yields due to drought. Insects were major cause for grain loss followed by rodents and molds.

				were analyzed in five project areas May 1979-June 1980.	
R.J. Lavinge,1991	Stored grain insects in underground storage pits in Somalia and their control	Insect Science and its Application, 12(5-6), 571-578.	Sorghum/Somalia	The methodology comprised of testing sorghum samples compartmentalized and stored based on crop species in underground storage pits commonly known as "bakars". Different chemical treatments were used for grains to see the effects on the loss levels.	Insects and rats were common pests. Plastic bags used in the experimentation were also infested. The mean percentage damage by insects in the region was 10.4 by insects and 8.4 by rats for sorghum stored as heads in 100 "bakars"
Seifelnasr, Y.E. 1992	Stored grain insects found in sorghum stored in the central production belt of Sudan and losses caused	Tropical Science, 32(3), 223-230	Sorghum/Sudan	The methodology to estimate the losses in stored sorghum used Adams and Schulten (1978) "weight loss and count method." The number of insects were captured and counted using bating traps. The percentage losses in sorghum was propotional to mean number of insects.	The mean weight loss of sorghum was between 2.5% and 7.6%. Ten insect species were found responsible for the losses. T. granarium is identified as world's most feared storage grain pest. 60% humidity and 33-370C temperature favor greatest rate of insect growth.
Nyambo, B.T. 1993	Post-harvest maize and sorghum grain losses in traditional and improved stores in South Nyanza district, Kenya	International Journal of Pest Management, 39(2), 181-187.	Maize and Sorghum/Kenya	Used "gravimetric method" to estimate losses at monthly intervals in maize and sorghum over a period of 4 months in Oyugis (OY) and Kandu Bay(KB) regions of Kenya during year 1990-91. The experiment was done to see the difference between traditional (TG) and improved granaries (IG).	Maize losses =2.2%, 5.6% (TG,IG): (OY) and 11.5%, 5.6% (TG,IG) :(KB);Sorghum losses- 3.6%, 6.15% (TG, IG) :(OY) and 7% 14.3% (TG, IG):(KB)
Mvumi, B.M., D.P. Giga, and D. V. Chiuswa,1995	The maize (Zea Mays L .) post-production practices of smallholder farmers in Zimbabwe	The Journal of the University of Zimbabwe, 12.	Maize/Zimbabwe	Two diagnostic surveys were conducted between 1990 and 1992 to evaluate the maize post-production practices of smallholder's farmers in Zimbabwe.	There was lapse of 4 months observed between physiological maturity of maize and shelling. 9.1±1.1 losses was observed at the yield level and 8.0 ±1.1 was lost at storage level. Cumulative losses was estimated to be 10.4 ±1.1 per cent of potential yield.
Compton, J. A., S. Floyd, A. Ofosu, and B. Agbo. 1998.	The Modified Count and Weigh Method: An Improved Procedure for Assessing Weight Loss in Stored Maize	Journal of Stored Products Research, 34(4), 277-285.	Maize /Ghana	Proposed a modification of Count and Weigh method by counting the destroyed grains on each cob and	Earlier methods underestimate the losses especially where grains are reduced to powder in insect infestation.

	Cobs			using adjusted calculation.	This was attempt made to improve the weight loss estimation procedures.
Compton, J. A. F., and J. Sherington. 1999	Rapid assessment methods for stored maize cobs: weight losses due to insect pests	Journal of Stored Products Research, 35(1), 77-87.	Maize/Ghana	Replaced count and weigh method by Visual loss estimation method for rapid assessment of losses.	Post-harvest weight loss estimates in the sample batches are in range of 4.8%-21.5%. Was stated as a faster method for loss estimations.
Pantenius, C.U. 1998	Storage losses in Traditional maize granaries in Togo.	Insect Science and its Application, 9(6), 725-735.	Maize/Togo	"The count and weigh method", "the standard volume/weight" and "the thousand grain method" were used to estimate the storage losses in traditional maize granaries for two years 1983-1985.	Count and weigh method was identified as best measurement method. 12-13% losses occurred after 6 months in stored hybrids whereas only 3% in the traditional methods.
Haile, A. 2006	On-Farm Storage studies on sorghum and chickpea in Eritrea	African Journal of Biotechnology, 5(17).	Sorghum and Chickpea/Eritrea	Tested insect treatments of sand, small grain, vegetable oil and chemical (Malathox 1%) for a year 2003/04. Collected data every month on number of eggs, number of holes, grain damage, weight loss, and germination of grains randomly picked from 20 storage bags of treated sorghum and chickpea.	The weight loss and germination both increased with the increase in period of storage. Weight loss was highest for teff treatment (6.83% to 9.75% for the sample). The germination for ash and chemical treatments were better when compared with other available alternatives.
Gangwar, L. S., D. Singh, and Singh, D. B. 2007	Estimation of Post-harvest Losses in Kinnow Mandarin in Punjab Using a Modified Formula	Agricultural Economics Research Review, 20(2).	Kinnow/India	Estimated supply chain losses in two harvesting methods and two marketing channels. Data was gathered during the fruit harvesting and marketing seasons through pre-tested questionnaire by personal interview method.	Post-harvest losses (PHLs) at the harvesting stage were estimated to be 10.63 % in first harvesting technique compared to only 2.51 % in second harvesting method. Medium distance PHLs were 5.15% whereas long distance were 10.63%.
Basavaraja, H., S. B. Mahajanashetti, and N. C. Udagatti. 2007	Economic Analysis of Post-harvest Losses in Food Grains in India: A Case Study of Karnataka	Agricultural Economics Research Review, 20(1).	Rice and Wheat /India	Estimated losses in cereals, rice and wheat for two post-harvest channels in India. Survey data was collected from 100 farmers, 20 wholesalers, 20 processors and 20 retailors for the year 2003-04.	Losses at the farm level were estimated at 3.82% per 100 kg for rice and 3.28% per 100 kg for wheat.