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Food Loss and Waste Definitions and Measurement Issues: The Case of the Maize Sector in Mozambique

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ABSTRACT

Current estimates point to food loss and waste as costing around $US 900 billion dollars a year. That is equivalent to around one-third of global food production. The magnitude of this valuation, however, is reliant on the effective measurement of the actual amount of food loss and waste. There are various definitions of this problem, which differ in their scope. FAO, FUSION and WRI are the most prominent institutions that have proposed different definitions of food loss and waste. All of these definitions have been at least partially criticized. Nonetheless, FAO's definition and methodology have been the basis for many studies attempting to quantify food loss and waste. FAO's methodology is based more on estimation rather than direct measurements. Taking the example of maize in Mozambique, using FAO's methodology to measure food loss and waste at the farm level seems to provide estimates comparable to the available statistics from the national agricultural surveys. Direct measurements on the other hand, apart from being costly, seem to suffer from representativeness problems as highlighted by some authors. Also, some of the direct measurement methods proposed by some authors seem to look at food loss and waste as a static problem, rather than a dynamic problem that evolves over time. Regardless of the level where the problem of food loss and waste occurs (upper or lower end of supply chains), it results in a deadweight loss for society. That is demonstrated by a Marshallian supply and demand diagram.

Keywords: Food loss and waste, definitions, measurement methods, limitations

1 Introduction

The problem of food loss and waste is long standing and recent estimates point to nearly 1.3 billion tons of food lost and wasted worldwide annually (FAO, 2018b). This volume (approximately one-third of global agricultural production) is equivalent to around $US 900 billion dollars (FAO, 2018b; WRI, 2016). Per capita food loss and waste is higher in Europe and North America (above 280 Kg) than in sub-Saharan Africa (around 170 Kg) (FAO, 2011, 2018b), nonetheless, its impact is relatively higher in that region of Africa. According to the World Food Programme (WFP, 2015), the undernourishment prevalence level is at 25 percent of the total population in sub-Saharan Africa, the highest in the globe.

In Mozambique, like in many other developing countries, food loss and waste is a major concern at the farm level, particularly for grain crops. Cugala, Tostão, Affognon, and Mutungi (2012) in their literature review of post-harvest losses (PHL) in Mozambique found estimates for maize ranging from about 12 to over 25 percent across the country. Hugo (2008) suggests that it could reach up to 40 percent at the farm-gate stage. In contrast, FAO food balance sheets suggest PHL levels at less than 10 percent (FAO, 2018a). The accuracy of all these estimates, however, is questionable. As Cugala et al. (2012) highlight, available relevant literature often lacks measurement adequacy (usually accounting only for the quantity of PHL caused by a particular pest or group of pests, such as insects or rodents, and disregarding part of the maize consumed previously by the household), the use of controlled experiments, and sampling representativeness. FAO estimates, on the other hand, are based on secondary information.

Overall, in Mozambique and in many other countries, PHL for cereals is likely related to farmers' traditional practices for grain storage (Cugala et al., 2012). Aligned to this, secondary factors are also important to explain PHL. In the case of Mozambique, natural hazards and pests are the main factors identified by farmers themselves (MASA, 2015, 2016). Although not often mentioned, marketing conditions that impact on farmers' decisions to sell, such as poor access roads and low prices, are also important determinants of observed PHL. Figure 1 summarizes the most likely important drivers of food loss and waste at the farm level in Mozambique in particular, and potentially in some other countries with a similar context.

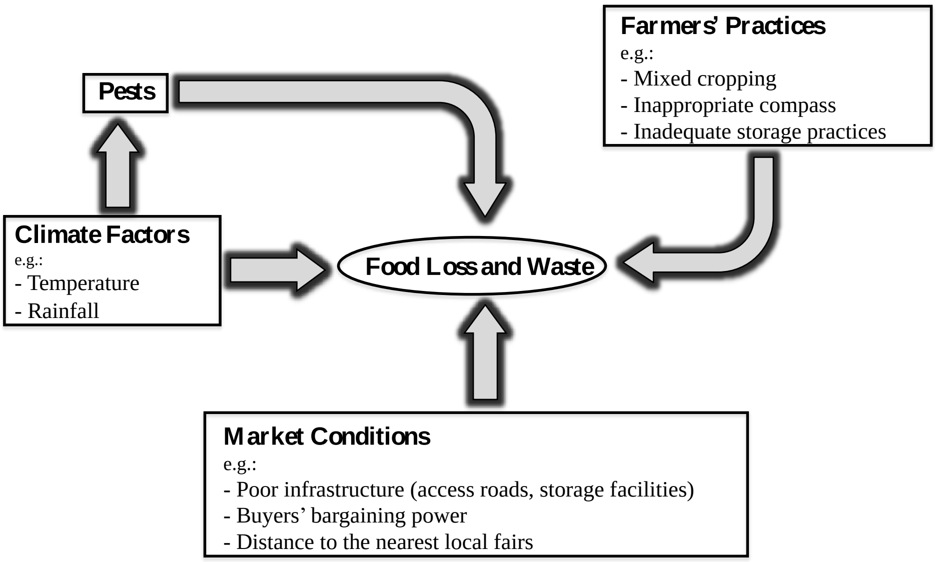


Figure 1. Key drivers of food loss and waste at the farm level in Mozambique

The problem of PHL at the farm level is acknowledged by the Government of Mozambique as an important issue (MASA, 2011). In the past, Government actions towards PHL issues included the promotion of improved silos to farmers and training of local artisans to make metal silos (Coulter & Schneider, 2004). However, these actions failed to address long-term sustainability (Cugala et al., 2012).

Recently, the Food, Agriculture & Natural Resources Policy Analysis Network (FANRPAN, 2017) suggested that metal silos and hermetic bags are effective alternatives to minimize PHL and raise farmers' income in Mozambique. The study was conducted at a micro level, disregarding the overall impact of PHL to a larger economy scale. This is likely one of the reasons why similar interventions may have failed in the past. To date, very few studies have attempted to put a value on the economy-wide implications of food loss and waste in Mozambique, in order to increase awareness amongst key stakeholders from different value chains that could result in long-term effective efforts to minimize the problem. However, the lack of such studies may be due to either a lack of adequate information, or the unreliability of the available statistics on PHL.

The aim of this paper is to review the major definitions related to food loss and waste, the main methods used to measure food loss and waste (PHL in particular) in cereals at the farm level, and the overall economic implications of this problem. This article contributes to the discussion on this problem of food loss and waste and the effectiveness valuation of the magnitude of the problem, focusing on small-scale economies. The focus is given to the maize sector in Mozambique, but may be extended to other grain crops and to other developing countries. Different methods to report PHL are likely to return different estimates that may result in different perceptions of the problem. The end result is long-term ineffective policy decisions.

2 From Definitions to Measurements: Food Loss, Food Waste or Food Loss and Waste?

Despite the long-standing interest in and the importance of the food loss and waste issue globally, agreement on a universal concept have not been reached. This lack of consensus results in different food loss and waste estimates and, thereby, limits the reliability of the available information.

For some, food loss and food waste seem interchangeable concepts. However, different institutions define the problem in different ways. FAO, for instance, defines food loss and food waste differently. Whilst food waste is defined as the decrease in quality or quantity of edible food mass intended for human consumption that occurs specifically at the end of the food supply chain, being mainly related to retailer and consumer behaviours, food loss is defined as an issue that takes place at any of the early stages of the supply chain – from production to processing – due mainly to issues such as logistics and infrastructure (FAO, 2011; Segré, Falasconi, Politano, & Vittuari, 2014). Although food that is considered to be loss and (or) waste can be diverted to other supply chains (e.g., as animal feed) as acknowledged by FAO, under the definition it is still classified as loss or waste based on the initial purpose of its production (FAO, 2011).

The European Commission (FUSIONS project) defines food waste differently. Under the FUSIONS's (European Commission) definition, the boundaries of food waste differ markedly from the FAO's definition. This new definition of food waste is broader by including inedible parts of food and not limiting food waste to the late stages of the supply chain.

> *"Food waste is any food, and inedible parts of food, removed[…] from the food supply chain to be recovered or disposed (including composted, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea)."* (Östergren et al., 2014, p. 6).

In 2016 a new definition was proposed by the World Resource Institute (WRI) as an attempt to standardize the concept of food loss and waste. WRI, in partnership with FAO, FUSIONS and other organizations, defined the food loss and waste protocol as the global standard for food loss and waste quantification (WRI, 2016). Under this protocol, food loss and waste is defined as any material (food, inedible parts of it or both) removed from the food supply chain by the time it is at least ready for harvesting, regardless of it being diverted to other destinations (Hanson et al., 2016a).

The WRI concept resembles an aggregation of the FUSIONS and FAO's definitions, which are regarded as the basis for the majority of the literature and the various definitions of food waste (and loss) (Cerciello, Agovino, & Garofalo, 2018; Chaboud & Daviron, 2017; Hartikainen, Mogensen, Svanes, & Franke, 2017; Parfitt, Barthel, & Macnaughton, 2010).

Some criticisms have been made of all three definitions. Chaboud and Daviron (2017) criticize the FAO's definition for accounting for the alternative uses of food intended for human consumption as food loss and (or) waste. For these authors, apart from the lack of consistency on this definition – by accounting, for instance, for the food diverted to animal feed as food waste (or loss) whilst disregarding from this category the crops grown for animal feed purposes – the argument is that alternative uses of food intended for human consumption (such as for animal feed) is not necessarily a waste (or loss).

Similarly, Hartikainen et al. (2017) criticize the inconsistencies on the FUSIONS's definition for the exclusion of particular alternative uses of food as food waste. FUSIONS's definition advocates that removed food (and or inedible parts of it) from the food supply chain that can be subject to valorisation or conversion within other supply chains, e.g., *"animal feed, biobased materials and biochemical processing"*, should not be referred to as food waste (Östergren et al., 2014, p. 23). However, for these authors all alternative uses of food should follow at least the same classification.

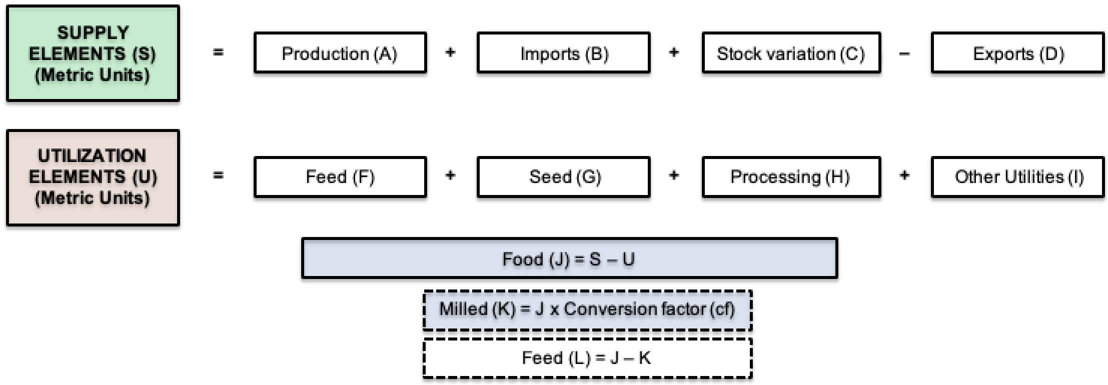
Hartikainen et al. (2017) also object to the inclusion of inedible parts of food (e.g., peels and bones) as food waste in the definitions from FUSIONS and WRI. For these authors, it should not be accounted as food waste. Though, the rationale from FUSIONS and WRI is to account for the cultural differences amongst countries or regions on what is edible and inedible food. Finally, Hartikainen et al. (2017) also point to some divergences between these two definitions on their guidelines for the starting point of non-crop supply chains (e.g., animal and fish), which have implications to food loss and waste quantification.

In an attempt to overcome the issues raised from past definitions, Hartikainen et al. (2017) propose the use of the term "Side Flow" to express the concept of food loss and waste as well as to account for the potential losses at the pre-harvest stage. Nonetheless, and as acknowledged by the authors themselves, there is not much differences between their concept of "Side Flow" and the FAO's definition of food loss. According to Hartikainen et al. (2017), the system boundaries and food loss and waste tracking at the primary production level from their study are similarly defined as in FAO (2011). Thereby, FAO's definition seems to be the widely accepted definition.

3 Food Loss and Waste Measurement Methods

Despite the differences in definitions, Reutter, Lant, and Lane (2017) point out that FAO's methodology for food loss and waste measurement has been the base for many studies. FAO's approach is an indirect measurement method based on food balance sheets and literature review (Gustavsson, Cederberg, Sonesson, & Emanuelsson, 2013). Under this methodology, food loss and waste is calculated based on some estimated or assumed coefficients. In the case of cereals for instance, food loss that can occur at the farm level is estimated based on a coefficient obtained by the ratio between the "other utilities" and supply elements (production, import and stock variation) from the food balance sheets. Other coefficients to estimate food loss (and waste) at other stages of the supply chain – e.g., from the processing to consumption levels – are based on literature reviews and are crop and technology specific for each country (or region). The FAO methodology to estimate food loss and waste is described in Figure 2.

Several other methods to estimate food loss and waste based on direct measurements (e.g., direct weighting, counting, diaries and surveys) and inference (e.g., modelling and proxy data) are also referred to by WRI and FUSIONS (Hanson et al., 2016b; Tostivint et al., 2016).



Segment	Food Waste (and Losses) Calculation (FW)	cf source
Agricultural production (pre-harvest)	$FW_A = [cf_1/(1 - cf_1)] \times A \times (K/S)$*	Literature review/assumptions
Postharvest handling and storage	$FW_S = cf_2 \times A \times (K/S)$	Calculation as $cf_2 = I/(A+B+C)$
Processing and packaging	Milling: $FW_M = cf_3 \times J$ Industrial bread baking: $FW_I = cf_4 \times (K + H - FW_M)$ Total: $FW_{PP} = FW_M + FW_I$	Literature review/assumptions
Distribution	$FW_D = cf_5 \times (K + H - FW_{PP})$	Literature review/assumptions
Consumption	$FW_C = cf_6 \times (K + H - FW_{PP} - FW_D)$	Literature review/assumptions

* This is the denominated allocation factor, used to express the loss of food at primary production that could potentially be used for human consumption

Figure 2. FAO measurement method of food loss and waste for cereals

Source: Adapted from Gustavsson et al. (2013)

Delgado, Schuster, and Torero (2017) also refer to other "direct measurement" methods, different from the ones mentioned by WRI and FUSIONS, which they have tested in some developing countries: self-reported, category, attribute and price methods. Whilst the self-reported method is based on respondents' self-assessment of perceived losses in terms of quality and quantity, the other methods rely on visual inspections against quality classification criteria defined *priori* by *"commodity specialists, local experts and value chain actors"* (Delgado et al., 2017). The price method is based on the assumption that price reduction represents a proxy for the reduced quality of the product. Hence, under that method, the difference between the actual production value and its potential value (considering an "ideal price") is used to estimate the volume and value of food loss. Results from Delgado et al. (2017) suggest that category, attribute and price methods do not display significant differences on food loss quantification at the producer level, and the values reported from these methods are considerably higher than the ones reported from the self-reported method. However, "direct measurement methods" such these are often associated with high costs of implementation.

4 Limitations from Current Measurement Methods of Food Loss and Waste

Measuring food loss and waste efficiently and effectively is a complex and challenging process. Though the FAO approach seems relatively simpler and cost-efficient compared to others, the major drawback from this methodology is the strong reliance on conversion factors (and assumptions) based mostly on literature reviews. The conversion factors required may not be available for every country and, when available, they may be outdated (Gustavsson et al., 2013). In the case of maize in Mozambique, for instance, information on "other utilities" is not reported from FAO's food balance sheet, that is required to generate the coefficient of food loss occurring at the farm level (as suggested in Figure 2). Coefficients from proxy regions might not fit adequately, which may result in high inaccuracy of estimates. Adding to that, based on FAO's definition, food loss may also be overestimated due to accounting for diverted uses of food as food loss. Some of these limitations (including limited accuracy and availability of some of the data required) and the overall limited accuracy of information from food balance sheets is acknowledged by FAO (FAO, 2001).

Other methods such as the ones proposed by Delgado et al. (2017) also display some limitations beyond the high costs of implementation. For instance, in the case of developing countries such as Mozambique, where farmers usually have limited access to market information (e.g., prices) and sell their produce to buyers (mostly small-scale retailers and other households) that are not strictly demanding on quality attributes, some of the methods proposed by Delgado et al. (2017) might not be appropriate.

Apart from the limitations raised early, in general most of the methodologies in place disregard the effects of biological processes and pest attacks that impact on food loss and waste. The "direct measurement methods" described by Delgado et al. (2017) are not clear about how timing of measurement impacts on estimates. As a result of biological activities, food loss and waste is more like a dynamic rather than a static process. Therefore, measuring food loss and waste only in one time period may not be appropriate.

Despite the major limitations, FAO's estimates of food loss and waste seem to be an adequate starting point to understand the magnitude of the problem. At least, this is likely the case in maize in Mozambique as discussed next.

5 Uncertainties in Food Loss and Waste Estimates for Maize in Mozambique

The central and northern regions of Mozambique are usually maize surplus producers and, hence, the regions where high levels of PHL are likely to occur in the country. Few empirical studies measuring PHL have been conducted in those regions. As shown in Table 1, estimates of PHL in maize vary substantially in the country. However, the validity of most of these PHL estimates are limited due to measurement errors or country-level representativeness (Cugala et al., 2012).

Estimates of PHL in Table 1 differ considerably from FAO estimates over the period 2000 to 2013. FAO reports point to PHL at about 3.7 to nearly 8 percent of the total maize production. These estimates are regarded as country-level representative. However, FAO estimates are not based on direct measurements. Despite that, FAO's estimates corroborate somehow with some of the PHL estimates from direct measurement.

In 2014 and 2015 for instance, less than 16 percent of the nearly 4 million small-scale maize farms at the time in Mozambique reported the occurrence of PHL in their farms (MASA, 2015, 2016). Considering the average production per farm in each year – about less than 500 Kg (using data from MASA, 2015, 2016) – and assuming that PHL can reach about 60 percent (nearly the highest reported in Table 1) of each farm's production, the overall PHL across the country are around the highest FAO's estimates over 2000-2013. Though, estimates from past empirical studies (indicated in Table 1) are likely to suffer from some methodological limitations as referred to earlier.

Table 1.
PHL levels reported in maize in Mozambique

Author(s)	PHL level	Causes of PHL	Description of the study
Cugala et al. (2007b) cited by Cugala et al. (2012)	25.5% to 61.5% (average of 41%)	Natural infestation from insects	Survey conducted to smallholder farmers from Manica and Tete (Centre of Mozambique). PHL assessed after 6 to 8 months of storage.
Belmain et al. (2002) cited by Cugala et al. (2012)	19% (treated group) to 55% (control group)	Natural infestation from rodents	On-farm trials with smallholder farmers from the Zambezia province (Centre of Mozambique). PHL assessed after 8 months of storage to two groups of farmers: treated (with break-backs traps) and control groups.

Author(s)	PHL level	Causes of PHL	Description of the study
Sitoe (2005) cited by Cugala et al. (2012)	7% to 25.6% (average of 11% in 6.5 months)	Natural infestation from insects	On-farm assessment over different periods after storage and different provinces: South of Mozambique • 10.5 months in Maputo (7% of PHL) • 9.5 months in Gaza (16.5% of PHL) Centre of Mozambique • 4 months in Sofala (25.6% of PHL) • 3 months in Zambezia (7.7% of PHL) • 2.5 months in Tete (9.8% of PHL)
Hugo (2008)	30% to 40%	On-farm drying and storage	Average PHL reported to cereals in general, including maize

6 Overall Economic Implication of Food Loss and Waste

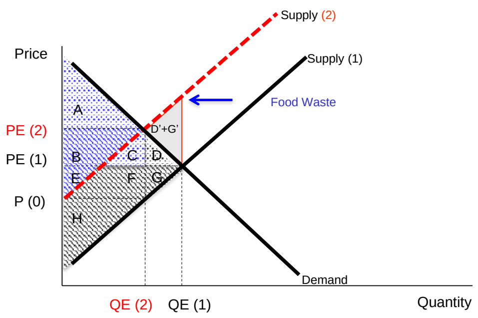
Wasting food, regardless of the segment of the value chain where it occurs, has significant implications for society. For instance, the opportunity cost of food loss and waste would be the provision of food for people who otherwise could not afford to buy it. In addition, food loss and waste is an inefficient way of allocating resources to food production that, at the same time, lead to unnecessary environmental damage either from greenhouse gas emissions during the production process or from the methane produced from food disposed in landfills (FAO, 2011; Reutter et al., 2017).

For efficient policy decisions towards food loss and waste, assessment of the economic magnitude of the problem is crucial to inform policy-makers about the cost-efficiency of potential interventions. Without a clear understanding of the magnitude of the problem, any intervention planned may not be realistic to solve the problem and it is likely to be short lived.

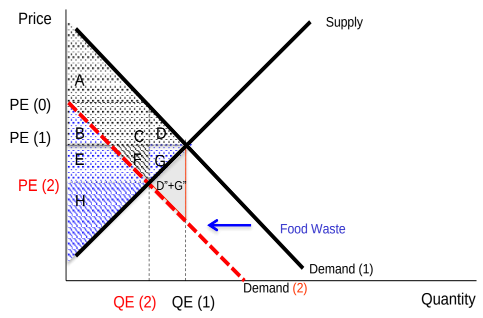
In Figure 3, a simplistic representation of the implications of food loss and waste is given from a Marshallian supply and demand perspective. Panel *a* of Figure 3 displays the implications of food loss at the supply side (e.g., producers) and panel *b* is about the food loss and waste at the consumption side (e.g., consumers). From the producers' perspective, wastage is an event that reduces quantity supplied of food, which results in higher market prices. However, because food (as a broad category) is a normal good without any close substitute, its elasticity of demand tends to be fairly inelastic (Mankiw, 2004) and, therefore, price changes tend to have huge impact on consumers. A similar outcome is obtained if food waste is viewed from the consumer side. In both cases, food loss and waste may result in a considerable deadweight loss as suggested in Figure 3.

In Figure 3, the negative impact of food loss and waste to society can be illustrated. Without food loss and waste, producer surplus (*E+F+G+H*) and consumer surplus (*A+B+C+D*) maximize society welfare. However, with food loss and waste on the supply side (panel *a* in Figure 3), the inability of producers to supply the initial equilibrium quantity (*QE (1)*) results in a higher market price (*PE (2)*). The end result is a reduction in both consumers and producers' surpluses and a deadweight loss for society. The deadweight loss represented by the area *D'+G'* in panel *a* represents a loss to society caused by the amount of food lost and wasted that prevents consumers to consume more food (Just, Hueth, & Schmitz, 2004; Mankiw, 2004). Similarly, with food loss and waste on the consumer side society fails to maximize total welfare; as shown in panel *b*, over consumption or purchases result in a deadweight loss equivalent to *D"+G"*.

Broadly, the example from Figure 3 is similar to the effects of negative externalities in production and consumption as described by microeconomic principles. In both panels *a* and *b* the market equilibrium price is at a higher price than the price in an efficient equilibrium. In practice, however, much complexity can be added to Figure 3 particularly, for instance, if one is interested in looking to the implications of food loss and waste from a multiple markets' perspective.



(a) Supply side



(b) Demand side

Figure 3. Theoretical impact of food loss and waste on the supply and demand sides

7 Conclusions

Food loss and waste is a global issue caused by different drivers at different stages of supply chains. Patterns of food loss and waste also vary according to the type of economies. In general, in medium and high-income countries the majority of food is wasted at later stages of supply chains (retailer and consumer levels) while in low-income countries food is wasted at earlier stages, particularly at the farm level. The concept of food loss and waste is not yet universally defined and different definitions of food loss and waste have been suggested over the years. The FAO's definition seems to be the most widely adopted. This definition makes a clear distinction between food loss and food waste. FAO's methodology to measure food loss is also commonly used in different studies. However, this and some other methodologies to assess food loss (particularly at the farm level), display some limitations in terms of accuracy. In the case of Mozambique, different estimates of food loss and waste are reported. Nevertheless, FAO's estimates seem the most appropriate to describe the magnitude of the issue across the country. That, in fact, supports the use of FAO statistics in many studies related to food loss and waste. Overall, food loss and waste makes society worse-off and this can be demonstrated using a Marshallian supply and demand framework.

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