Assessing the Measurement Methods of post-harvest Food Loss and Waste: Opportunities and Challenges

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Abstract:

Understanding the magnitude of Food Loss and Waste (FLW) and where in the value chain they occur can provide policy perspectives in targeting innovations and business opportunities to reduce FLW. Since the seminal FAO report on global FLW and the adoption of SDG 12.3, there has been a surge of research efforts quantifying FLW in recent years. However, there is disagreement over how best to measure FLW. Without reliable data on FLW, it will be challenging to derive policy and action toward targeting the hotspots of FLW. In this synthesis, we review the available tools for measuring FLW, their advantages and disadvantages, and a comprehensive assessment of their ranking in terms of accuracy, cost, and meaningfulness. The methods for quantifying FLW may vary according to the stages and types of a food supply chain for which different resources and technical capabilities are required. Therefore, a strong call for standardising methodologies for FLW quantification is imperative to harmonise measurement tools and methods.

Keywords: Food Loss, food Waste, post-harvest losses, measurement methods, food security.

1. Introduction

Food loss and waste (FLW) reduction is an essential pathway to food and nutrition security (FAO 2011; HLPE 2020). The current global FLW has a significant impact on the environment, economy, and food security. The impact represents an estimated 8 percent of annual GHG emissions, the annual loss in the economy at an astounding $940 billion, a loss of a quarter of all water used by agriculture, and a loss of 1 billion metric tons of food per year where one in nine people are still undernourished (FAO et al. 2018). Such a volume of the global impact of FLW is alarming. It highlights the urgency to reduce post-harvest food loss and waste. The recent report from EAT-Lancet Commission (Willett et al. 2019) has identified halving FLW as a critical element in achieving a sustainable food future, which is in line with the target of SDG 12.3 (halving the rates of FLW by 2030).

Since the seminal 2011 FAO report on global FLW and the adoption of SDG 12.3 in 2015 (UN 2015), there has been a surge of research efforts quantifying FLW in recent years (Xue et al. 2017; Spang et al. 2019). This body of research finds that a significant amount of FLW occurs at all the stages of various commodity supply chains. However, the volume of research is skewed towards a few countries (e.g., the United States and the United Kingdom) (Spang et al. 2019). Overall, the reported loss figures from primary production to retail are more widespread in developing countries, while food waste is more dominant at the household consumption level in developed countries (Hodges et al. 2010, WRI 2016, FAO 2019).

Along with the member countries, FAO has placed a research priority on developing and improving cost-effective methodologies for estimating FLW (Global Strategy or GSARS 2017; FAO 2018). Recent research identified insufficient quantification of FLW based on rigorous methods. Without reliable data on FLW, it will be challenging to derive policy and action toward targeting the hotspots of FLW. FAO has just published updated global and regional estimates of food loss in this effort. In contrast, food waste data are yet to be published (FAO 2019). Kitinoja et al. (2018) conducted a meta-analysis of FLW studies from 2006 to 2017. They found that about 41 per cent of studies used surveys, about 37 per cent used mixed methods, and only 7 per cent used direct measurement methods to quantify FLW. Sheahan and Barrett (2017) found that about 20 per cent of FLW studies used empirical field-level primary data collection. Xue et al. (2017) reviewed global FLW data. They found that only around 20% of the existing publications were based on primary data collection and called for the urgent need for FLW data collection based on direct measurement.

Lack of understanding of the location of losses and associated factors within the food supply chains remains a significant challenge for soperationalising FLW mitigation strategies. Overall, food losses can be measured in quantitative and qualitative terms, although most of the research has focused on the quantitative measure (Sheahan and Barrett, 2017). Quantitative losses occur when the actual physical losses of food happen, while qualitative losses occur through the loss of nutrients, visual aesthetic appeal, or food contamination amongst other factors (Sheahan and Barrett, 2017). Affognon et al. (2015) highlight the importance of understanding at which nodes in the value chain losses occur, at what levels, and what socio-economic factors influence such losses. sTo decide on various FLW reduction strategies along the food supply chain it is important to measure FLW with varying levels of precision and granularity. Quantifying FLW information can provide an evidence-based foundation for prioritising FLW hotspots in a food supply chain and help makieng policy to reduce FLW. Moreover, it will also help valorise waste and seek to create enterprise opportunities in this space based on evidence from FLW studies.

''The methods for quantifying FLW may vary according to the stages and types of a food supply chain for which different resources and technical capabilities are required. For example, understanding hotspots of losses in a smallholder's value chain may require fine- tuned data on types of loss (due to insect, spillage, etc.) and their location of occurrence in the value chain. On the other hand, to monitor a country's progress toward a policy target may only need a rough estimate of aggregated FLW figure. Despite abundant recent literature on quantifying FLW, comparability between their FLW estimates remains limited. This is mainly attributed to the lack of an internationally agreed FLW standard. Identified shortcomings include inconsistent FLW definitions and measurement methods. In response to this issue, in 2016, the Food Loss and Waste Accounting and Reporting Standard (WRI 2016) guided measuring and reporting of FLW. FLW standard has defined the term 'FLW' as a reduction in the weight of edible products available for consumption. This definition is convenient and simple and practical for researchers and institutions. It has proven adequate to be applied uniformly.

In this review, we investigate the available FLW definitions and measurement methods, their advantages and disadvantages, and our recommendations for improving the efficiency of such methods. The primary objective of this paper is to synthesise the current knowledge on FLW definitional frameworks and widely accepted measurement methods; Figure 1 depicts the framework which was followed for this review paper.

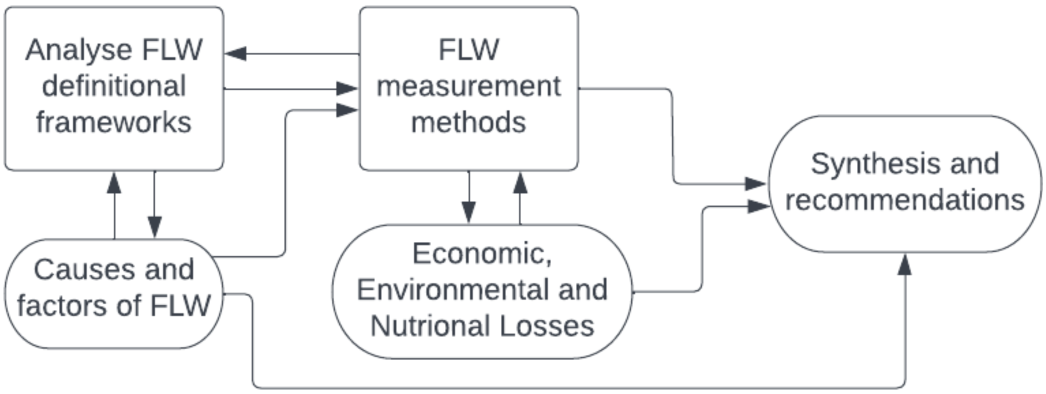

Figure 1: Research scope and framework of the review paper.

2. Causes and factors of FLW across the food supply chain

Understanding the root causes of FLW along the food supply chain is very important to determine what methods can effectively capture the quantity lost or wasted for a specific food crop. A cause is defined as an immediate reason for FLW, while a factor is defined as an underlying driver of creating the reason (WRI 2016; CEC 2019). Globally there has been a rapid transformation of food supply chains, especially in developing countries (Reardon et al. 2018). These changes influence the quantity of FLW at the supply chain stages. The drivers behind these transformations include globalisation, infrastructure improvement, urbanisation, and sspecialisation in the food industry , which shift the technology, access, and food preferences (Parfitt et al. 2010; Reardon et al. 2018). In Table 1, we list various possible causes and factors of FLW by stages of a food supply chain, including primary production, storage, processing and packaging, distribution and wholesale market, retail, and household consumption.

Table 1: Examples of causes and factors for FLW for the Food Supply Chain (FSC). (Source: Author's analysis)

	Past sale-by date	Over-purchase	Lack of cooking knowledge
			Overc

Steps in Food Supply Chain	Production	Storage, processing and packaging	Distribution and wholesale	Retail	Household consumption
	During or immediately after harvest on the farm	*After leaving the farm for storage processing and packaging*	*During distribution to wholesale market*	*Food Service and retail market*	*Cooking and consumption at home*
Direct causes of Food loss and waste (FLW)	Spillage	Eaten by pests	Physical damage	Food cooked but not eaten	Food cooked but not eaten
	Physical damage	Spillage	Spoilage	Spoilage	Spoilage
	Damage from pest and animals	Trimming during processing	Rejected from the market	Product recall	Past sale by date
	Discards due to bruising	Rejected from the market	Past sale by date	Past sale by date	
Inherent factors of FLW	Premature or delayed harvest	Poor storage facilities	Lack of cold chain	Failure in demand forecasting	Over purchase
	Poor harvesting equipment	Inefficient processing	Poor transportation	Prepared improperly	Lack of cooking knowledge
	Price volatility	Mechanical error	Demand issue	Too large portions	Overcooking

3. Food loss and waste definitional framework, index and databases

As mentioned in Section 1, the lack of a standardised definition for FLW has led to several interpretations. Table 2 summarises the definitions starting from the first definition in 1977 to the most recent definition in 2020.

Table 2: Various food loss and waste definitions, terms and their contexts.

Year	Summary of definition	Context	Terms	Reference
1981	Product edible for human consumption (dry weight basis) is known as food and, therefore, food avoided by consumers due to varying parameters i.e., quality & availability in market was considered as **food lost or wasted**	Food (All)	Food Loss & Waste	**Bourne, 1977, FAO, 1981**

1994	**Post-harvest loss** (i.e., FLW) is **quantitative & qualitative loss** of product including losses at the stage of harvest in turn leading it to being feed for animals	Food (All)	PHL, Loss	**De Lucia, M. & Assennato D., 1994**
2002	**Food loss** includes any modification that leads to both **quantitative and qualitative losses.** Damage during harvest such as rodent infestation is not considered within this framework	Food (All)	Food Loss	**Grolleaud, M., 2002**
2011	**Food loss** is a subset of post-harvest losses and represents the part of the edible share of food that is available for consumption at either the retail or consumer levels but not consumed for any reason	Food (All)	Post-harvest	**Hodges, 2011, Fusions, 2014**
2012	**Food that is unsuitable for sale** at the full price but is required to be sent to various kinds of waste management.	Food (All)	Food Loss	**Møller 2012**
2013	**Post-harvest losses** starts when the food in focus has reached its maturity in field. This also included the series of activities conducted starting from field all the way up to consumer	Cereal grains	PHL, weight losses	**APHLIS, 2013**
2014	According to this definition, **food loss is loss in quantity & quality of food** and further expand and encompasses the term food waste by considering it as food lost due choice consumer or supply chain actors or being overall unfit for consumption.	Food (all edible products)	Food loss, food waste	**Parfitt, Barthel et al. 2010; Parfitt 2011, Foresight 2011, FAO, 2014**
2014	The quantity of **food lost at post-harvest that is available for human consumption but not consumed** due reasons such as lack proper storage; supply system or food handling practices has been interpreted as food loss. Food waste is a part of food loss and occurs when an item fit for consumption goes	Food (all edible products)	Food Loss	**Buzby, Farah-Wells, and Hyman, 2014, FAO, 2017**

	unconsumed, due to changes in colour or overall appearance, or neglect by consumers.			
2016	**Waste of any food matter including both edible and inedible parts** of food that is removed from the food supply chain to either be recovered or disposed is defined as food waste in this framework.	Food (edible& inedible)	Food waste	Fusions, 2016
2017	**Food waste is defined as all the food that accounts into the landfill** across each stage of the supply chain	Food (all)	Food waste	Bellamare et al., 2017
2019	**Food Loss Index (FLI) is defined as the food lost starting from the production stage all** the way up to the retail stage but not including the losses in retail stage	Food (in general)	Food Loss Index	FAO;
2020	Food Waste Index (FWI) is defined as the food including all the inedible parts being removed across various stages of the food supply chain (manufacturing, retail, wholesale, & consumers)	Food (in general)	Food waste Index	UN Environment, 2020

Of the varying definitions mentioned in Table 2, the definition developed from the Food Use for Social Innovation by Optimising Waste Prevention Strategies (FUSIONS) and the Resource Efficient Food and drink for the Entire Supply Chain (REFRESH) Project is commonly implemented within the EU framework for FLW. The FUSIONS definitional framework includes both edible and inedible fractions of food into food waste categories. This is majorly done to encompass the quantification of waste and resource efficiency in the food supply chain, including adding, all waste categories. However, the FUSIONS project also recommends measuring edible and inedible parts separately to identify interventions better. Building on the FUSIONS definition, REFRESH defined consumer food waste as food and drink fractions edible from products/meals intended for consumption but unconsumed discarded. This definition is based on research on specific behaviours of consumers. It further adds that as consumers are often not in control of the destination of the discarded food that leaves their home (or their out-of-home site), food waste is scoped here to involve the stages from acquisition through discarding within the household or out-of-home boundary.

One of the most recent definitional frameworks (Van Greffen et al. 2016) considers food loss as the losses up to the market stage and food waste, everything starting from the market, including the consumer stage. Thus, considering both the definitional framework built from FUSIONS and REFRESH Project. However, it is essential to successfully implement and provide accountability to these terms, quantifying the losses across the value chain. For this research purpose, the focus is on the edible food fractions within consumer food discards. It will be referred to as 'food waste' in the remainder of the study. Other scientific studies within the consumer behaviour body of literature also follow this scope (Katajajuuri et al., 2014; Stefan et al., 2013; Stancu et al., 2016).

4. FLW measurement methods, their advantages, and disadvantages

With significantly large numbers of food loss and waste globally, measurement methods allow quantifying the losses and help assess their impact on economic, environmental, and social levels. The choice of measurement methods largely depends on the study's objective, the commodity selected, the stages of a food supply chain, and the resources available for the assessment. The selection of the units (farm, household, firm, location) and appropriate sampling design are also crucial before applying an FLW measurement method. Table 3 describes the various available measurement methods, their applications, advantages, and their disadvantages. The methods described in Table 3 align with FLW Protocol and standard (WRI, 2016).

Table 3: FLW measurement methods, their advantages, and disadvantages

FLW measurement methods	Key advantages	Key disadvantages

Weighing	• Directly counted or weighed • Often most accurate measurement of FLW • Allows to track	• Direct measurement can be expensive, time-intensive • Access to farm facilities is required • May lead to behavioural change (e.g., stimulate FLW prevention activities). Thus, making baseline measurement less accurate.
Waste composition analysis	• Measured by physical separation, weighing, and scategorising food waste. • Provides relatively accurate data on FLW.	• Relatively expensive and requires a large sample size. • May not be useful to track the cause of FLW. • Cannot be applied to all stages of FSC • Estimation can be affected by moisture losses in hot weather conditions.
Counting	• A low cost yet efficient method • Requires consistency and appropriate assumptions to deliver accurate measurements	• Inconsistent calculations or assumptions can lead to inaccurate data set. • this method can be opted for measuring only one kind of FLW. • Multiple FLW (varying in size, product) could enhance the discrepancies
Surveys (interviews)	• A cost-effective way to collect quantitative estimates of FLW and • Provides information about their causes. • Provide FLW data including information on various characteristics of the participants. • Interviews can be conducted using in-person, telephone, and an electronic questionnaire.	• Information is the perceptions of the participants • A recall bias and hence lead to inaccurate data • Need to be considered as a rough estimate of FLW. • Participants may underestimate waste due to aspirational bias.

Records	• Records such as waste transfer receipts, warehouse receipts, donation receipts, etc. can be used to quantify FLW for a few stages of FSC. • Useful method in food distribution and retail sectors where food inventory and waste management data are tracked. • Can be used supplement to other methods of measuring FLW.	• Can be used only for a few stages of the supply chain where useful records are available. • Accuracy depends on the quality of the collected records. • Not useful to track the type of food wasted.
Diaries	• Dairies provide the log of amount and type of food is lost or wasted along with how and why the FLW was discarded. • Could be printed, electronic, and smartphone app. • Can gather information on food waste going into sewer or composting	• Can be relatively expensive, especially when the participants are provided with some incentives. • May underestimate the amount of waste due to aspirational biases. • Participants may underreport due to "diary fatigue"
Mass balance	• Measures FLW by comparing inputs (e.g., product entering a facility) and outputs (e.g., product going out). • Cost-effective when there exists input and out data.	• Potential high inaccuracy depending on the input and out data. • Difficult to track the causes of FLW.
Proxy data/ literature data	• used to estimate FLW for a unit when there are no other resources available for conducting other methods • A low-cost method for a rough estimation of FLW.	• Data is usually unreliable • Should only be a starting point.

Over the years, several platforms have been established to quantify FLW that implement the measurement as mentioned techniques above. These include platforms such as the African Postharvest Losses Information System (APHLIS), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the International Food Policy Research Institute (IFPRI). The APHLIS measurement model allows practitioners in the field to assess the estimated loss at a specific region or area in focus. This model is majorly focused on evidence-based data that is obtained through observation (usually direct). This information is further combined with evidence from scientific research. As the model is based on a combination of scientific research and observation-based data, the potential of missing data or being incomplete is to be considered. The GIZ methodology allows for the assessment of losses across a rapid value chain. In this tool, the quantification is based on participatory approaches previously tried and tested in the field. Improvements to the tool are through the outcomes from the participatory approach. The IFPRI methodology takes an all-rounded approach to the measurement of losses both in a quantitative and qualitative manner by using surveys as a measurement tool. The survey includes the stakeholders at each processing stages of the food supply chain. These platforms are being used for specific commodities or countries and sometimes adapted for quantifying losses of a new product. To assess these methods, Table 4 ranks the methods and their application in the food supply chain. Since the choice of appropriate methodology depends on the commodity, supply chain stages, and resources available, etc, the Food Loss and Waste Accounting and Reporting Standard (FLW Standard) developed a decision tool to help sorganisations select appropriate methods (WRI 2016). Examples of direct measurement include weighing unharvested produce in fields (Johnson et al. 2018), weighing hospital food (Dias-Ferreira et al 2015), measuring food waste in school catering (Buzby and Guthrie 2002; Falasconi et al 2015), scanning items discarded or donated from supermarkets (Tesco 2018).

Examples of waste composition analysis include sorting and weighing FLW in mixed waste streams (Lebersorger and Schneider 2011; WRAP 2012) and household-level food waste composition studies (Dahlén et al. 2008; Bernstad et al. 2015). Among the abundance use of the survey-based method, Kaminski and Christiaensen (2014) and Shee et al. (2019) used respondents' self-reported perceptions of the post-harvest losses occurring at each post-harvest stage, van Herpen et al. (2016) assessed in-home food waste measurement using consumers self-reported information. Examples of using records include using the wasted mass of the products in the supermarket (Eriksson et al. 2014; Scholz et al. 2015). Regarding dairies, Langley et al. (2010) implemented individual household-level diaries to analyse compositional domestic food waste. The mass balance method is widely used to estimate FLW by comparing production and consumption of food volumes (Gustavsson et al. 2011; Buzby et al. 2014; Hall et al. 2009). The use of proxy data in the literature includes loss assessment in food retail (Lebersorger et al. 2014), food wastage at the household (Grandhi et al. 2016) and integrating data from multiple sources (WWF-WRAP 2020).

Table 4: Ranking of FLW measurement methods and their application in the food supply chain

FLW measurement methods	Commonly used for FSC stage	Accuracy	Cost	Time required	Meaningful (track causes)
Weighing	1,2,4,5	High	High	High	**Yes**
Waste composition analysis	2,3,4,5	High	High	High	**No**
Counting	1,4,5	High	Low	Low-Medium	**Yes**
Surveys (interviews)	1,5	Low-Medium	Medium-High	Low-Medium	**Yes**
Records	1,2,3,4,5	Low-High	Low	Low	**No**
Diaries	5	Low-Medium	Medium	Low	**Yes**
Mass balance	2,3,4	Medium	Low	Low	**No**
Proxy data	**1,3,4,5**	**Low**	**Low**	**Low**	**No**

Notes: *Food Supply Chain (FSC) stages are the following: 1= Production; 2= Storage, processing and packaging; 3= Distribution and wholesale; 4= retail; 5= Household consumption*

5. Sampling design for accurate quantification of FLW

FLW measurement methods described previously are scategorised as an objective measurement of physical loss and subjective assessment by respondents. Many of the previously mentioned studies estimating an FLW level did not follow suitable statistical methods, for example. They hence may not reflect the accurate and representative loss level at the regional or national level (Ahmad et al. 2016). Before any data collection and measurement, the observation units (food samples, bags, farmer, field, consumer,) should be selected using an appropriate statistical sampling design for rigour and validity. The recommended sampling design is probability sampling, where a unit is selected based on a random process, ensuring that every unit of the sampling frame has a known probability of selection. Probability sampling can be performed using a random number generator or table. Random sampling can be conducted when a list of the members of a population or sample frame is available (Jha et al. 2015; Ahmad et al. 2016; GSARS 2017; FAO 2018). The rationale for using probability sampling is that it ensures statistically representative measures for different locations, groups, regions, countries. The estimates generated by probability sampling methods can be considered representative of the targeted population, such as at regional and national levels.

It is essential to highlight the difference between probability sampling and purposive sampling. While a random selection is ensured in probability sampling, researchers choose sample units for practical reasons, which are proximity, and participants self-selection in purposive sampling. Purposive or non-probabilistic sampling has two main disadvantages:
1) Since the selection is not random, it is impossible to attribute a selection probability (sample weights) to each unit, thus precluding the researcher from extrapolating the results representative of the entire target population. 2) Non-probabilistic selection may generate bias in the estimates. For example, if farmers in the selected sample are in the process of implementing loss mitigation measures and are interested to know if their strategies are effective, purposive selection of such farmers will result in biased PLW measurement for the region.

Overall sampling design is defined by the number of selection stages (one or more stages), the stratification (by agroecological zone, farm size, etc.), and the sample selection procedure. Unit units can be selected at each stage based on a probability sampling described before. Typically, agricultural survey-based FLW measurement in developing countries is based on several stages of random selection (Fabi et al 2021). Apart from probability sampling, selecting an appropriate number of units (sample size) is important for precision and statistical representativeness. The targeted sample size is usually a compromise between the available budget and the properties that the analyst or policymaker requires for the final estimate for FLW. The optimal sample size can be calculated through a formula relating sample size, the targeted standard deviation, and the budget allocated to the study. Moreover, it is crucial to determine how the FLW data will be used or what are the main objectives for collecting such data before the measurement study is initiated.

6. Translating food loss and waste into financial, environmental, and nutritional indicators

Translating FLW physical amounts (mainly represented in tonnes per annum) into more relatable indicators such as financial (economic), environmental (in for of GHG emissions) and nutritional (daily calorie requirements per person per annum) is common practice to convey the message to different disciples of research and to the policymakers (APHLIS, 2018; Sheahan, &Barrett 2017). As per the latest report (2021) of the World Economic Forum, the annual cost of FLW to the global economy was $936 billion. Moreover, the food systems costs were $12 trillion in terms of health, economic and environmental costs. There are tools available online which can quantify the economic loss of food waste at each step of the value chain. APHLIS (African Postharvest Loss Information Systems) is one initiative that translates the FLW into economic and nutritional value. This is particularly important for business in the current scenario where sustainability and net zero are actual targets for everyone. One such example is a recent case study from Olam Agri. Olam Agri has the pledge to reduce the FLW in their direct supply chains by 50% by 2030 (APHLIS, 2022). Looking at the environmental costs, current estimates suggest that FLW emits close to 4.4 Gt of CO2 eq per year, accounting for approximately 8-10 % of the global anthropogenic greenhouse gas (GHG) emissions. According to the Food and Agricultural Organisation (FAO), 1.3 billion tonnes of food are either lost or wasted worldwide, roughly one-third of the total food production. These levels of FLW accounts for 30% of the world's agricultural land and 38% of the total energy consumption of worldwide food systems. Reducing these vast amounts of FLW and enhancing the energy efficiencies of our food systems provides an excellent opportunity to augment sustainability, meet the growing demand for food and mitigate climate change. United Nations Sustainable Development Goals 12.3 set a clear target of halving food waste by 2030 and highlight the interdependence of reducing FLW on climate change mitigation. The Paris Agreement (2015) on climate change action also recognises the linkages between climate change, food production systems, and food security.

7. Integrative approach and recommendations

A significant problem with using a survey-based method is that the responses are subjective because they are based on the opinion of respondents and may not be accurate. Estimates coming from subjective methods may be affected by a declarative bias because the farmer may lack knowledge of his or her losses. Moreover, such methods require people to try to recall or remember what happened in the past, sometimes weeks, months, or even a season before collecting the information. Hence, the survey-based FLW measurement should generally be less accurate than direct measurements of FLW. Only a few studies have compared the objective and subjective measurements of FLW. As part of their research activities on post-harvest loss, Global Strategy conducted a pilot survey in Ghana to compare the objective and subjective methods for loss measurement (GSARS, 2017). They find that objective measurements generally lead to higher loss estimates than subjective measurements. The main advantage of survey-based measurement is that it is more cost-effective and less time-consuming than direct measurement and waste composition analysis. The survey-based method can be a vital measurement method when it is combined with other measurement methods. Information collected by both survey methods and direct measurement can be combined by using sophisticated estimation approaches. For example, improved FLW estimation can be obtained from the regression of losses from direct measurement of losses from the survey and a range of farm characteristics. Such estimated parameters could also provide quick and reliable loss projections (WRI, 2016).

Because the FLW measurement methods vary by stages in a food value chain a proper agricultural value chain analysis should be conducted before any FLW measurement, to fully scharacterise and decompose the chain (actors, cost structures, etc.) and identify the FLW hotspot stages (FAO, 2018; Parmar, 2018). It is also essential to choose the relevant value chain actors according to their role in the supply chain: grain producers, processors, transporters, sellers. The already available data from value chain analysis could be used in assessing FLW for specific stages of a value chain. For a value chain analysis, the most important principle is to map the actors participating in a crop's production, distribution, sales, and retail. The mapping scharacterises the actors and quantifies the flows of crops along the chain, which could be efficiently used in FLW quantification. Such details can be gathered from a combination of primary survey work, focus groups, participatory rural appraisals, informal interviews, and secondary agricultural data. For each targeted hotspot stage, different loss measurement methods can be used.

FAO's recently published State of Food and Agriculture (FAO 2019) provides an order-of-magnitude understanding of the scale of global FLW. However, the data is skewed towards a few developed countries (e.g., the United States and the United Kingdom) and a few stages in the food supply chain (e.g., household consumption), while the extent of FLW in developing countries and other stages of food supply chain remains largely unexplored. There has been a significant data gap and inconsistency among data sources, as most of the FLW data are based on secondary sources. To minimise this data gap the literature calls for standardising of methodologies for FLW quantification that future studies should uniformly follow. The standardisation should include the definition of FLW, stages of the food supply chain, the destination of FLW. As only about 20 per cent of existing literature on FLW quantification is based on primary data, there is an urgent need to collect primary data, especially the data collected based on direct measurement methods.

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