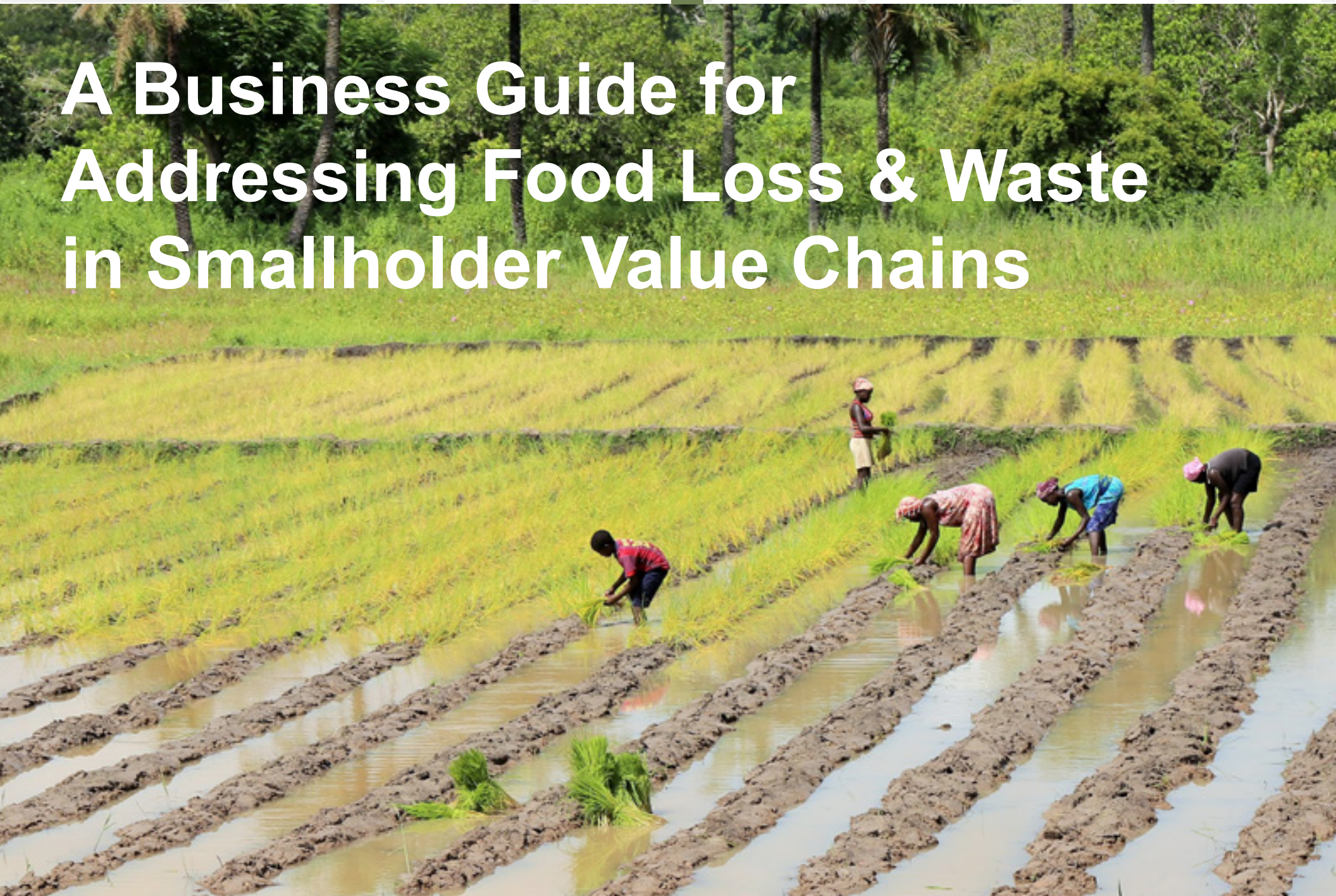
A Business Guide for Addressing Food Loss & Waste in Smallholder Value Chains



Introduction

Efficiency is paramount in our food systems. And addressing food loss and waste is one very effective way to move towards increased efficiency.

Until recently, supply chain food loss and waste (FLW) has been somewhat invisible to many companies. Yet, a reduction in upstream FLW is an opportunity; not only to increase bottom lines, but also to deliver on critical (and often difficult to achieve) sustainability commitments like reduced green house gas emissions (GHGs), increased resource use efficiency, improved farmer livelihoods, and food security.

When the FLW movement began years ago, much emphasis was placed on waste at the consumer level in developed countries. And for many years, large food and beverage companies have been addressing FLW in their own operations. Working back from there, buyers have begun to work with suppliers to understand FLW in their supply chains. For the most part, companies have addressed FLW with highly professionalized growers, as those are the most visible. Today, smallholder supply chains and family farms in the developing world are the frontier, in terms of uncovering opportunities to reduce FLW and to increase the profitability and sustainability of our food systems.

Smallholder Supply Chains Present a Meaningful Opportunity to Reduce Food Loss & Waste Globally

Since 2014, the Sustainable Food Lab has been working with the Rockefeller Foundation as part of their Yieldwise Initiative aimed at reducing food loss and waste globally. The Food Lab has been focused on supporting food and beverage companies that source from smallholder producers in Africa to better understand the scope of the FLW opportunity. Initial dialogue with global food companies uncovered key questions around smallholder supply chain FLW that guided the Sustainable Food Lab's work:

1. **When is measurement of FLW necessary?**
2. **How do we determine which supply chains to invest in?**
3. **How can we leverage FLW as an opportunity to deliver on our commercial and sustainability goals?**
4. **What does a practical, business-friendly approach to FLW assessment look like?**
5. **What lessons are other companies learning about measuring and reducing FLW?**

In 2017, the Sustainable Food Lab partnered with Wageningen University & Research (WUR) and the Cool Farm Alliance (CFA) to undertake a number of activities aimed at addressing these questions.

Deep dive interviews with 40 multinational food companies—the world's leading input providers, traders, processors and retailers—helped us to understand their orientation and questions regarding supply chain FLW and the relative importance of their smallholder sourcing. To respond to Questions 1 and 2, WUR conducted a FLW Hotspot Analysis of African smallholder value chains to understand where FLW was most prevalent and most impactful in terms of its social and environmental effects. Interviews were also conducted with the world's top experts on FLW measurement to understand where they felt like the biggest opportunities for learning occurred. Regarding question 3, one of the high leverage synergies is the potential to both measure and reduce FLW and GHG emissions. In response, the Cool Farm Alliance developed a FLW Module to be included in their global industry calculator, the Cool Farm Tool.

Addition materials on reducing smallholder FLW can be found at:
sustainablefoodlab.org/initiatives/food-loss-and-waste

Sainsbury/VP Group

Crop: French Bean
Geography: Kenya
Number of farmers in the value chain: 1,700

59%
FOOD LOSS WASTE

Overview of methodology: 30 farms were evaluated, providing 3 samples each that were tracked and followed throughout the value chain

Key FLW reduction investments identified:
- Creating awareness with regard to the extent and impact of losses
- Capacity building for application of standardised good agricultural practices

Read more

Olam

Crop: Rice
Geography: Nigeria
Number of farmers in the value chain: 22,700

35%
FOOD LOSS WASTE

Overview of methodology: 60 farms were evaluated, providing 3 samples each that were tracked and followed throughout the value chain

Key FLW reduction investments identified:
- Creating awareness with regard to the extent and impact of losses
- Capacity building for application of standardised good agricultural practices

Read more

Finally, in response to questions 4 and 5, as part of the partnership between the Sustainable Food Lab, WUR, and the Rockefeller Foundation, two multi-national companies were engaged in pilots to design and roll out practical methodologies to measure and assess the FLW that occurs within their smallholder value chains.

In Nigeria a pilot was set up with Olam to understand the magnitude and impact of FLW in their outgrower rice initiative. In Kenya a pilot was set up with Sainsbury and VP Group (formerly Vegpro) to look at FLW in their smallholder French bean value chain.

From these pilots, the Sustainable Food Lab and WUR added to their growing body of knowledge about when FLW measurement in smallholder value chains is necessary, when it is practical, and how to approach it in a way that will lead to valuable insights. The later, providing information into which investments could reduce FLW and deliver on important business and sustainability goals. These learnings are shared in this guide developed for sustainability professionals within national and multi-national food and beverage companies.

Seven Steps to Measuring FLW in Smallholder Value Chains

1. Prioritize Where to Focus Your Efforts
2. Design a Measurement Approach
3. Gather and Analyze Data, and Calculate Inventory Results
4. Socialize Findings
5. Use Data to Inform FLW Reduction Strategies
6. Track the Impact of FLW Investments & Integrating FLW Data Collection into Supply Chain ICT
7. Partner to Reduce FLW

1 Prioritize Where to Focus Your Efforts

In conversations with those working on sustainability and FLW in food and beverage companies, common questions are, “How do we determine what ingredients and what origins to start with? How do we assess where FLW is a material issue to our company?”

In the Olam pilot, the company determined that rice in Nigeria was a priority because:

- They had a desire to contribute to Nigeria’s food security efforts by increasing security of supply of locally sourced rice.
- There is significant GHG and water use associated with rice.
- They wanted to understand what proportion of emissions, water, and other resource use went to rice that is wasted.

In addition to the WUR FLW Hotspot Analysis, there has been an effort to answer these questions within WBCSD’s FReSH program through the development of the Food Loss and Waste Value Calculator created by Quantis. The Value Calculator is designed for users to compare and contrast the environmental and nutritional impact of efforts to reduce food loss and waste. It uses secondary data to create a snapshot of the impacts related to the loss and waste of different types of food. The Value Calculator is intended to help companies to determine which food loss and waste streams to prioritize.

There isn’t always a simple answer to the question of where to focus FLW reduction efforts, but there are a number of useful guiding questions that can help clarify the decision making process.

In general, it will likely be most impactful to invest in measurement of FLW in chains where the following is true:

- The companies in the chain have commercial interest in reducing FLW because the ingredient is significant in terms of volume, spend, or reputation
- The ingredient is resource or labour intensive and therefore a sustainability risk
- The ingredient is sourced from a region with high poverty and/or food insecurity, and better supply chain efficiency could help overcome livelihood challenges
- The ingredient is an important cash crop for producers and increased production and sales could improve farmer livelihoods significantly
- Supply chain partners have influence and visibility at the farm level in this chain and infrastructure exists to work with farmers to measure FLW

Even when all of these criteria are met, it can still be difficult to make the case to invest time and money in a FLW measurement effort. Every supply chain has its own characteristics and specific workings hence, tailored measurement approaches are required. Measurement in smallholder chains is logistically challenging and time consuming, yet we have determined from our work that, in the case of FLW, direct measurement is important. Data shows that farmer self-reported loss and waste quantities are highly irregular and direct measurement is critical for an accurate assessment. When a company makes it a commitment to address FLW in their smallholder chains, it is recommended that they undertake at least one in-depth study, serving as a baseline. Advice for how to conduct an in-depth food loss and waste measurement is described in the steps below. This approach will then allow the company to extrapolate process learnings from the in-depth study to apply to other supply chains and FLW measurement efforts, therefore increasing the return on investment for an in-depth study. More on how to get a higher return on investment from a FLW study can be found in Step 6.

2 Design a Measurement Approach

Once a company has determined where to focus their FLW measurement and reduction efforts—the crop and geography—they can identify the goals so as to design a tailored approach to measuring FLW in this supply chain. The steps mentioned hereafter follow the Food Loss and Waste Standard (see Figure 1). Several elements and steps have been added based on the experience obtained through piloting the measurement approach.

Figure 1: Overview of steps in FLW Accounting and Reporting[1]

1. FLW Standard

Define Goals *FLW Standard Step 1*

The first step of a FLW measurement pilot is to define the goal of the measurement. This can be related to food security, economic performance, environmental impact, or a combination of several goals. Typically, smallholder producers are most interested in decreasing FLW to increase the economic performance of their crop or improve their family's food security through increased income or improved yield. Other local chain actors, like intermediaries, hauliers or input providers, can have similar goals. Overall, international companies may then combine these goals with outputs like reducing environmental impact, GHG emissions or water use. Typically, company goals with regard to smallholder value chains are related to learning how to make farmer businesses more profitable, stimulating acceleration of FLW efforts, or increasing food security, amongst others.

In our work with Olam's rice value chain in Nigeria, the company identified the following goals that helped guide the development of their measurement methodology:

- Test the practicality of a measurement approach in order to replicate it at scale across other rice origins
- Identify critical loss hotspots during on-farm activities
- Increase awareness on the FLW subject and train farmers and Olam supply chain managers on reduction efforts
- Make the business case for quantifying FLW to Olam supply chain managers and farmers by demonstrating the direct benefits of reducing FLW in terms of reduced cost of production and increased volumes.

Establish Study Scope *FLW Standard Step 3*

The scope of a study can differ substantially. Therefore, when designing a tailored measurement methodology, it is important to break down in detail all activities conducted by all supply chain actors. It is also helpful to understand the current product flow in the supply chain to visualize the roles of each actor, and their potential role in FLW reduction. Figure 2 shows an example of a supply chain process with different activities. If possible, stakeholders and product flows should be identified from producer to consumer ('farm to fork').

After mapping the product flow, a supply chain process with different activities that are expected to incur a high level of loss should be prioritised as part of the project measurement scope. Additionally, the information regarding the definition of food loss, like including or excluding inedible parts, considering whether valorization of the products into animal feed is a food loss or not, should be considered.

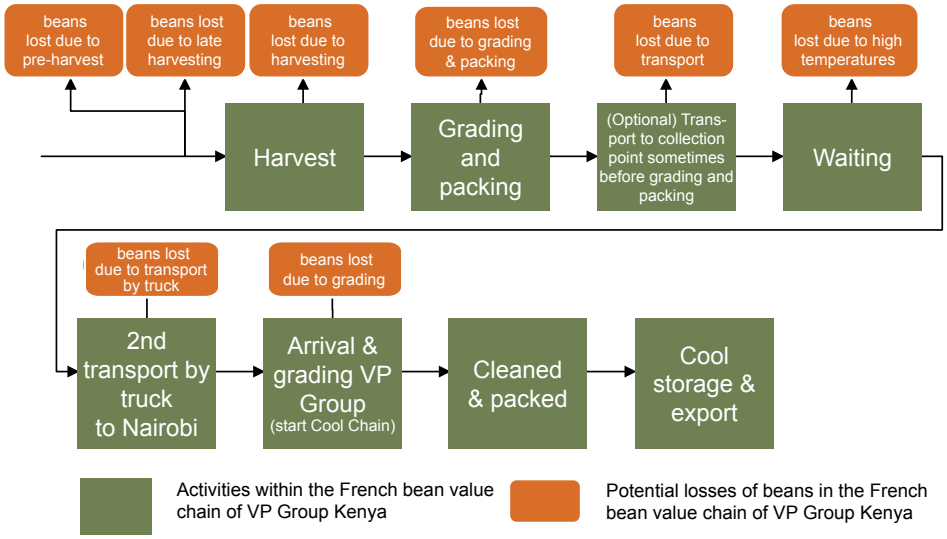


Figure 2: Product Flow Chart, VP Group's French bean chain, Kenya.

Review FLW Accounting and Reporting Principles & Decide How to Quantify FLW *FLW Standard Steps 2 & 4*

Within these steps, stakeholders should engage in dialogue on required levels of rigor, i.e, data quality, reliability, accuracy and consistency before the actual measurement protocol is designed.

Available company data can be assessed in terms of quality and reliability. If the data is up to the required standards, the scope of data collection can be reduced. For example, if a company collects reliable data on approved and rejected produce per producer, this can be used in the FLW measurement effort, instead of performing separate measurements to gather this data.

Smallholder producers do not tend to record production data and may not have been exposed to concepts around Food Loss and Waste measurement approaches. Smallholder farmer records and recalls are not sufficiently reliable and therefore direct field measurement involving weighting or counting are needed to provide more reliable data insight. There is a side opportunity to engage early on with smallholder farmers to help validate the root causes around loss, increase farmer awareness of post-harvest loss and bring them on the journey to see the direct benefits to reduce loss in terms of resource efficiency and income gains.

The FLW Standard can help with defining the right measurement strategy, like direct measurement, counting and interviews among others. The approach should be selected based on the questions the company is looking to answer, such as where loss occurs and why or how much exactly is being lost to establish a baseline to work from.

After selecting the right reporting and measuring strategy, a company can continue with the product flow chart of the supply chain as described above. This is the starting point for designing the measurement methodology. If critical FLW loss points are already known, based on research results or secondary data, the focus of measurement can concentrate on those hotspots. The following recommendations are made when required to complete farmer surveys or direct measurements on-farm:

Interviews: When building a survey to interview farmers, use the different activities in the supply chain to structure the questionnaire.

Direct measurements: Measurements should always take place before and after each activity stage measured, with the difference in weight or number being the product loss (minus the moisture content when applicable). For example, measure the weight of the product before transporting and measure the weight of the product after transporting. Note that the best way to measure differs per crop and per supply chain. Examples of measurement methodologies and registration forms used in the rice chain in Nigeria and the French bean chain in Kenya can be viewed in Appendix B and Appendix C. These measurement methodologies can be used as a starting point for designing the methodology for the selected product-supply chain combination.

A critical point of attention is whether or not to include and log moisture content in the measurement methodology. This can be the case for cereal crops, which tend to change in weight based on moisture content. Some cereal crops need to be dried to a certain moisture content level before processing, storage or packing can take place. For example, high moisture level during storage encourages the development of molds or can lead to grain discoloration, which decreases the quality of the product. In the case of cereal crops, keeping track of moisture content loss throughout the activity stages or, at least, keeping the difference in mind from the point of harvest to the point of storage, processing, or sale is important to not confuse actual product volume loss with

moisture (water) content loss. Lastly, companies should consider if the cause(s) of FLW need to be taken into account in direct measurements or whether they can be gleaned from interviews. Typically, the causes of loss are best identified through interviews.

Establish Sample Size *FLW Standard Step 7*

It is critical to ensure that measurement efforts yield useful, representative data. Therefore the sample size should be established before collecting the data. Prior to measurement, farm typologies are established based on farm size, location, and other factors like whether they use specific types of mechanisation. Taking farms characteristics in consideration, the farms should be randomly selected to ensure the data from the sample group is representative of the farms assessed.

While a larger sample size generates more reliable results, the resources are not always available to conduct such a study. The sample size is determined by the required confidence interval and the level of uncertainty (see Appendix C). If project resources do not permit a large sample, consider reducing the sample size based on available resources: consultant and coordination capacity, time and funding. The use of a smaller sample size in the pilot can still give useful results.

Stakeholder Engagement Workshop

This step in addition to those in the FLW Standard, is critical for ensuring local stakeholders are engaged in the effort and quality data is collected. Before implementing the measurement methodology, two activities should be conducted with local stakeholders:

1. Introduction of the pilot goals and process
2. Validation of the measurement methodology

Introduction of the pilot to producers and the local field team is important as the study cannot be conducted without their participation and cooperation. The local field team is the link between smallholders and companies, providing valuable buy-in and context.

Producers are the experts in the field. Their input can help validate

	Production	On farm sorting and grading	Packing and labelling	Transport and waiting at central collection point	Transport to Nairobi packhouse	Sorting and grading at Nairobi packhouse
ACTIVITIES	Land Preparation	Waiting	Waiting	waiting	waiting	cold chain
	Production	Transporting	Packing	loading	weighing	transport
	Pest and Disease management	Sorting and Grading	Labelling	transport	loading	sorting and grading
	Harvesting	Cleaning	weighing	unloading	transport	processing
	Packing	Waiting	Waiting	register and weighing	waiting	packaging
	Transporting			waiting	unloading	transporting
ACTORS	Land owner	Lead Farmer	Lead Farmer	Lead Farmer	Lead farmer	Driver
	Lead farmer	VegPro field coord	Labourers	Labourers	Coordinator collection point	Offloaders
	VegPro agronomist	Labourers		Coodinator collection point	Driver	VegPro staff
	VegPro field coord	Sainsbury		Driver		Sorters and Graders
	VegPro sprayers					
	Labourers					

Table 1: Overview of activities taking place at each stage and involvedness of different stakeholders

the measurement scope and methodology; Are all activities with potential high losses included? Are the measurements possible in practice? Are the questions in the interview understandable and of interest? Involve producers and field staff in mapping out the specific activities taking place at each stage of the supply chain and highlighting the activities and stages where they feel losses occur.

Examples of topics to introduce and discuss during the workshop are:

- Intended project goals and potential value to farmers
- Raising awareness of food loss and waste
- Data confidentiality
- Sharing feedback and learnings post-pilot

If the locations of the farms are not mapped, it can be useful to travel to the region to map out the area and select the farms beforehand. Frequently, only employees or government extension staff operating in the province or village have a good overview and are able to find all relevant farms. This makes it difficult to select a sample completely at random. Besides, smallholders are often located near each other and copy each others farming practices. Be aware of this, and when needed, group the farmers per cluster in the region of interest. Therefore, it is best to select the sample as randomly as possible, based on the number of farmers per town and typology of farms, if required.

3 Gather and Analyze Data, and Calculate Inventory Results *FLW Standard Steps 5 & 6*

After the stakeholder workshop, the measurement methodology can be validated by performing a test run in the field. Perform an on-site test measurement with the measurement protocol designer(s) and the enumerators. In case of interviews, conduct a few test interviews. Adapt the measurement methodology and survey structure based on the feedback received.

Finally, the implementation of the field measurements can start. During data collection, it is advised to check the collected data daily for accuracy and data anomalies. This will allow for adjustments to the data collection methodology and will avoid the collection of unusable data. If possible, build controls into data collection tools that will produce a notification when incorrect data, or data that is out of expected ranges, is entered.

The Cool Farm Tool (CFT) FLW Module is a new FLW data collection tool and calculator that can be considered as well. While it is not designed specifically for smallholder value chains, enumerators can use the CFT FLW Module to assess the GHG and water use impacts of FLW based on the loss data and production data obtained through direct measurements. The CFT FLW Module is designed to record food loss and waste occurring in production, first level processing, and transport and then look at this data alongside that same farm's GHG emissions in order to understand areas for improvement in efficiency. The tool is free for farmers. Using real data from farms to create calculations.

After data management and data cleaning, data can be analyzed, and results presented. It is important to take into account that the causes of loss might happen in one stage in the supply chain but show up at a later stage in the supply chain. If an activity or stage in the supply chain is considered as a critical FLW point, it does not automatically mean that the solution is best implemented here. For example, when entering a large warehouse, agricultural products are screened, graded or simply rejected due to quality deterioration which will lead to loss. The cause of the loss however, might have occurred on farm, during transport, through extended sun exposure, or a variety of other factors.

Interviews and observation can help to understand the root causes of loss and identify the specific step in the supply chain where the loss actually occurred. Therefore, both interviews and observations are critical in gathering the contextual information needed to make sense of why loss is happening and what can be done to reduce it.

4 Socialize Findings *FLW Standard Step 9*

After data is analyzed, the results should be presented to the stakeholders involved in the supply chain and those involved in data collection. Presenting the results (including critical FLW points) and relating loss to the impact on farmer incomes and resource use efficiency, should lead to a discussion where ideas and measures to reduce losses can be exchanged. This discussion can also lead to the identification of potential interventions, or follow up studies, that can result in a reduction of losses and improvements in other metrics like smallholder incomes, food security, reduced greenhouse gas emissions and/or water use. Validation of assumed yield and calculated losses should be conducted by asking stakeholders questions and having them reflect. These assumptions can be triangulated with producers and other supply chain stakeholders.

5 Use Data to Inform Food Loss and Waste Reduction Strategies

As with any investment in data collection, it is important to use the FLW data to inform reduction efforts and investments. This seems obvious, yet despite the time and money spent on measurement, too often it seems this data can get overlooked when teams are deciding how to invest in reducing FLW in their supply chain. Focus must be placed on where and why FLW is happening along the chain to determine where resources are best spent. Often times, there are low-cost investments to be made at or near farm level that can significantly reduce loss. These investments, like providing farmers with tarpaulins, may not be as flashy as new state-of-the-art technology, but can prove to be impactful interventions.

Some of the most important data to examine when investing to reduce FLW in smallholder chains is whether there is a business case and return on investment for farmers. The business case should be clear to producers before asking them to make an investment. Ideally, they will see returns on these investments in relatively short order.

For example, will hiring additional laborers to harvest more rapidly cost more than the value of the produce at risk of becoming degraded and lost in their absence? Or will planting rice in ordered rows lead to significant loss reduction on the cultivated land area but will also reduce the land use intensity per ton of product, meaning that farmers would end up losing less but also producing less yield on the same land area. These are few of the questions that require attention before interventions are considered as ultimately, the goal is for farmers to be economically better off while reducing pressures on the environment.

Data should be used to perform ROI calculations on these types of questions before recommending specific investments on behalf of

smallholder producers. The only way for a FLW reduction investment to be successful is if it is profitable (and arguably, easy as well) for all parties involved.

It may also be necessary to support farmers to change practices by connecting them with access to capital or other resources. Companies are not necessarily solely responsible for providing these resources to producers, partnerships with governments and NGOs can be established (see step 7 for more information on partnering).

6 Track the Impact of FLW Investments & Integrating FLW Data Collection into Supply Chain ICT *FLW Standard Step 10*

Once an in-depth study has been conducted, the results can serve as a baseline to set targets, monitor and evaluate progress and impact of a particular investment or intervention. The baseline study informs a FLW strategy and supports the set-up of a data collection system to monitor progress on FLW targets.

This system can simply be a selection of data points collected at the critical loss points that have been identified in the supply chain. Data can be collected with tools that support the visualization of key results and impacts at different levels.

Smallholder farmers should be supported to evaluate and assess the impact of on farm interventions through cost effective periodic measurement.

In a multi stakeholder supply chain where a company supports and provides advice to smallholders the anchoring companies can help support monitoring efforts and assess the impact of the strategy and intervention.

7 Partner to Reduce FLW

Because FLW in smallholder supply chains is a relatively new space for a lot of companies, conversations with peers about FLW is a critical step for industry adoption and alignment. Discussing with peers and suppliers on topics such as: how they are measuring FLW, what they are investing in and how they incentivize suppliers to reduce FLW, can be valuable to create sector-wide change. The willingness of pilot partners such as Olam, Sainsbury and VP Group to provide thoughtful feedback along their journey as well as their willingness to share the approach they have taken in their respective supply chains and engaging other companies through industry groups and forums is much needed to keep on building momentum and deliver on industry targets to reduce food loss and waste. The Sustainable Food Lab and WUR hope to facilitate more of these conversations as more companies adopt smallholder FLW measurement and reduction strategies.

The importance of collaboration between stakeholders within the supply chain cannot be stressed enough. Supporting loss reduction through cost effective, high impact measures on farm, (pre-harvest and post-harvest) can significantly improve farmers' livelihoods whilst reducing losses as products move downstream hence improving overall supply chain efficiency.

There are several platforms through which companies can engage with their peers to learn and act together to reduce FLW. Some of the platforms that are convening peer companies on reduction of FLW in smallholder supply chains include:

Cool Farm Alliance
WBCSD's Global Agri-Business Alliance
WBCSD's FReSH Initiative
Champions 12.3
FAO Community of Practice on Food Loss Reduction
The Global Initiative on FLW Reduction (SAVE FOOD)
Consortium for Innovation in Post-Harvest Loss and Food Waste
Waste and Resources Action Programme (WRAP)

8 About this Guidance Document

This guide was developed for sustainability professionals within national and multi-national food and beverage companies. Content was created by the Sustainable Food Lab in collaboration with Wageningen University & Research and with support from the Rockefeller Foundation, Olam International, VP Group and Sainsbury's.

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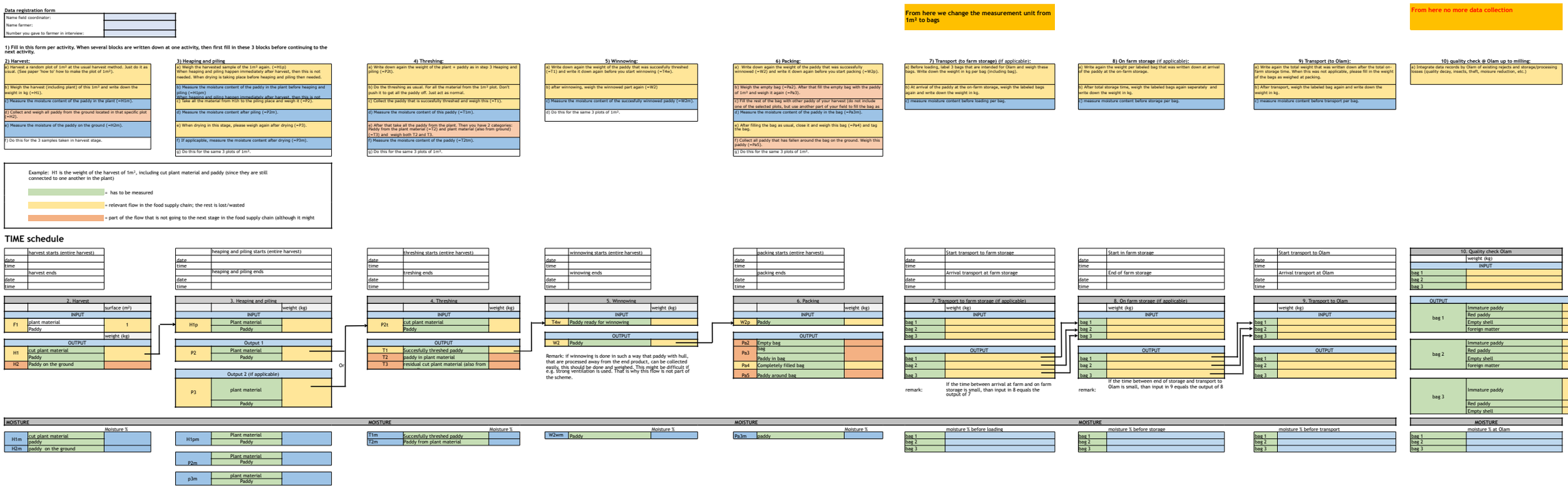
Appendix A: Where to Prioritize Investment in Food Loss & Waste

The sheet below can be used to compare multiple crops, allowing companies to prioritise their efforts to reduce FLW. Circle the number that best corresponds with your answer.

CROP					
1. How significant is this ingredient in terms of:	significant				not significant
Spend	1	2	3	4	5
Volume	1	2	3	4	5
Reputation (high visibility)	1	2	3	4	5
2. How resource intensive is this ingredient? Would reduction in FLW make an impact on these environmental factors?	significant				not significant
GHGs	1	2	3	4	5
Water	1	2	3	4	5
Agri-inputs (also counted on GHGs)	1	2	3	4	5
GEOGRAPHY					
	food security				food insecurity
1. Are you sourcing this crop from a developing country with significant amounts of poverty and/or food insecurity?	1	2	3	4	5
	significant				not significant
2. Is this crop a meaningful source of income for producers?	1	2	3	4	5
	no/weak				yes/strong
3. Does this country have any local sourcing requirements in place that you are working to meet?	1	2	3	4	5
	no/weak				yes/strong
4. Do you have smallholder technical assistance or support infrastructure in place to easily access farmers and influence change?	1	2	3	4	5
	few				many
5. How many farmers are in this value chain?	1	2	3	4	5
TOTAL SCORE					

Appendix B: Full Data Form



Appendix B: Expanded Data Form (steps 1-4)

Data registration form

Name field coordinator:	
Name farmer:	
Number you gave to farmer in interview:	

1) Fill in this form per activity. When several blocks are written down at one activity, then first fill in these 3 blocks before continuing to the next activity.

2) Harvest:

a) Harvest a random plot of 1m² at the usual harvest method. Just do it as usual. (See paper 'how to' how to make the plot of 1m²).
b) Weigh the harvest (including plant) of this 1m² and write down the weight in kg (=H1).
c) Measure the moisture content of the paddy in the plant (=H1m).
d) Collect and weigh all paddy from the ground located in that specific plot (=H2).
e) Measure the moisture of the paddy on the ground (=H2m).
f) Do this for the 3 samples taken in harvest stage.

3) Heaping and piling

a) Weigh the harvested sample of the 1m² again. (=H1p) When heaping and piling happen immediately after harvest, then this is not needed. When drying is taking place before heaping and piling then needed.
b) Measure the moisture content of the paddy in the plant before heaping and piling (=H1pm) When heaping and piling happen immediately after harvest, then this is not
c) Take all the material from H1h to the piling place and weigh it (=P2).
d) Measure the moisture content after piling (=P2m).
e) When drying in this stage, please weigh again after drying (=P3).
f) If applicapble, measure the moisture content after drying (=P3m).
g) Do this for the same 3 plots of 1m².

4) Threshing:

a) Write down again the weight of the plant + paddy as in step 3 Heaping and piling (=P2t).
b) Do the threshing as usual. For all the material from the 1m² plot. Don't push it to get all the paddy off. Just act as normal.
c) Collect the paddy that is succesfully threshed and weigh this (=T1).
d) Measure the moisture content of this paddy (=T1m).
e) After that take all the paddy from the plant. Then you have 2 categories: Paddy from the plant material (=T2) and plant material (also from ground) (=T3) and weigh both T2 and T3.
f) Measure the moisture content of the paddy (=T2tm).
g) Do this for the same 3 plots of 1m².

Example: H1 is the weight of the harvest of 1m², including cut plant material and paddy (since they are still connected to one another in the plant)

= has to be measured

= relevant flow in the food supply chain; the rest is lost/wasted

= part of the flow that is not going to the next stage in the food supply chain (although it might

TIME schedule

	harvest starts (entire harvest)
date	
time	
	harvest ends
date	
time	

	heaping and piling starts (entire harvest)
date	
time	
	heaping and piling ends
date	
time	

	threshing starts (entire harvest)
date	
time	
	treshing ends
date	
time	

2. Harvest		
		surface (m²)
INPUT		
F1	plant material	1
	Paddy	
		weight (kg)
OUTPUT		
H1	cut plant material	
	Paddy	
H2	Paddy on the ground	

3. Heaping and piling		
		weight (kg)
INPUT		
H1p	Plant material	
	Paddy	
Output 1		
P2	Plant material	
	Paddy	

Or

Output 2 (if applicable)		
P3	plant material	
	Paddy	

4. Threshing		
		weight (kg)
INPUT		
P2t	cut plant material	
	Paddy	
OUTPUT		
T1	Succesfully threshed paddy	
T2	paddy in plant material	
T3	residual cut plant material (also from	

MOISTURE

		Moisture %
H1m	cut plant material	
	paddy	
H2m	paddy on the ground	

H1pm	Plant material	
	Paddy	
P2m	Plant material	
	Paddy	
p3m	plant material	
	Paddy	

MOISTURE

		Moisture %
T1m	Succesfully threshed paddy	
T2m	Paddy from plant material	

Appendix B: Expanded Data Form (steps 5-7)

From here we change the measurement unit from 1m² to bags

5) Winnowing:

a) Write down again the weight of the paddy that was succesfully threshed (=T1) and write it down again before you start winnowing (=T4w).
b) after winnowing, weigh the winnowed part again (=W2)
c) Measure the moisture content of the succesfully winnowed paddy (=W2m).
d) Do this for the same 3 plots of 1m².

6) Packing:

a) Write down again the weight of the paddy that was successfully winnowed (=W2) and write it down again before you start packing (=W2p).
b) Weigh the empty bag (=Pa2). After that fill the empty bag with the paddy of 1m² and weigh it again (=Pa3).
c) Fill the rest of the bag with other paddy of your harvest (do not include one of the selected plots, but use another part of your field to fill the bag as
d) Measure the moisture content of the paddy in the bag (=Pa3m).
e) After filling the bag as usual, close it and weigh this bag (=Pa4) and tag the bag.
f) Collect all paddy that has fallen around the bag on the ground. Weigh this paddy (=Pa5).
g) Do this for the same 3 plots of 1m².

7) Transport (to farm storage) (if applicable):

a) Before loading, label 3 bags that are intended for Olam and weigh these bags. Write down the weight in kg per bag (including bag).
b) At arrival of the paddy at the on-farm storage, weigh the labeled bags again and write down the weight in kg.
c) measure moisture content before loading per bag.

	winnowing starts (entire harvest)
date	
time	
	winowing ends
date	
time	

	packing starts (entire harvest)
date	
time	
	packing ends
date	
time	

	Start transport to farm storage
date	
time	
	Arrival transport at farm storage
date	
time	

5. Winnowing		
		weight (kg)
INPUT		
T4w	Paddy ready for winnowing	
OUTPUT		
W2	Paddy	

Remark: if winnowing is done in such a way that paddy with hull, that are processed away from the end product, can be collected easily, this should be done and weighed. This might be difficult if e.g. strong ventilation is used. That is why this flow is not part of the scheme.

6. Packing		
		weight (kg)
INPUT		
W2p	Paddy	
OUTPUT		
Pa2	Empty bag	
Pa3	bag	
	Paddy in bag	
Pa4	Completely filled bag	
Pa5	Paddy around bag	

7. Transport to farm storage (if applicable)	
	weight (kg)
INPUT	
bag 1	
bag 2	
bag 3	
OUTPUT	
bag 1	
bag 2	
bag 3	

remark: If the time between arrival at farm and on farm storage is small, than input in 8 equals the output of 7

MOISTURE

		Moisture %
W2wm	Paddy	

		Moisture %
Pa3m	paddy	

	moisture % before loading
bag 1	
bag 2	
bag 3	

Appendix B: Expanded Data Form (steps 8-10)

From here no more data collection

8) On farm storage (if applicable):

a) Write again the weight per labeled bag that was written down at arrival of the paddy at the on-farm storage.
b) After total storage time, weigh the labeled bags again seperately and write down the weight in kg.
c) measure moisture content before storage per bag.

9) Transport (to Olam):

a) Write again the total weight that was written down after the total on-farm storage time. When this was not applicable, please fill in the weight of the bags as weighed at packing.
b) After transport, weigh the labeled bag again and write down the weight in kg.
c) measure moisture content before transport per bag.

10) quality check @ Olam up to milling:

a) Integrate data records by Olam of existing rejects and storage/processing losses (quality decay, insects, theft, moisure reduction, etc.)

	Start in farm storage
date	
time	
	End of farm storage
date	
time	

	Start transport to Olam
date	
time	
	Arrival transport at Olam
date	
time	

10. Quality check Olam	
	weight (kg)
INPUT	
bag 1	
bag 2	
bag 3	

8. On farm storage (if applicable)	
	weight (kg)
INPUT	
bag 1	
bag 2	
bag 3	

OUTPUT	
bag 1	
bag 2	
bag 3	

9. Transport to Olam	
	weight (kg)
INPUT	
bag 1	
bag 2	
bag 3	

OUTPUT	
bag 1	
bag 2	
bag 3	

OUTPUT		
bag 1	Immature paddy	
	Red paddy	
	Empty shell	
	foreign matter	
bag 2	Immature paddy	
	Red paddy	
	Empty shell	
	foreign matter	
bag 3	Immature paddy	
	Red paddy	
	Empty shell	

remark: If the time between end of storage and transport to Olam is small, than input in 9 equals the output of 8

MOISTURE	moisture % before storage
bag 1	
bag 2	
bag 3	

	moisture % before transport
bag 1	
bag 2	
bag 3	

MOISTURE	moisture % at Olam
bag 1	
bag 2	
bag 3	

Appendix C: Sample Size

Estimating the food waste percentage (=fwp) for a certain product requires sampling of the population, in this case production areas or farms. In general when the population is high it is common practice to assume that fwp is normally distributed with some mean p and variance p(1-p)/n, where n is the sample size. Let's say the estimate of p is $\hat{p}$, then the equations for the sample sizes are[1]:

Unlimited population $$n = \frac{z^2 * \hat{p}(1-\hat{p})}{E^2}$$

Finite population $$\tilde{n} = \frac{n}{1 + \frac{z^2 * \hat{p}(1-\hat{p})}{E^2 * N}}$$

Where z is the z-score (choose according to required confidence level), E is the margin of error (you want to be sure that with some confidence level the value is within ($\hat{p}$ -E, $\hat{p}$ +E)) and N is the population size.

So the levels of freedom are: confidence level and margin of error. Each combination implies a different sample size. Shown in the table these combinations are shown with their corresponding sample size. These calculations are carried with the formula for unlimited population. In most cases the real population N will be much larger than n and one can easily see that in this case the formula for the finite population is almost the same as the one for the unlimited population. Hence the sample size will hardly deviate for the formulas above. The table below can be used to decide upon the sample size based on resources like capacity and funding.

Confidence Level / Margin of Error	85%	90%	95%
5%	208	273	385
10%	52	69	97

Table 1: Sample size for various combinations of conf. level and margin of error

The formulas above can be used as well for other combinations of confidence level and margin of error.

1 https://www.calculator.net/sample-size-calculator.html