Reality of Food Losses: A New Measurement Methodology

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Abstract

Measuring food loss, identifying where in the food system it occurs, and developing effective policies along every stage of the value chain are essential first steps in addressing the problem of food loss and waste in developing countries. Food loss has been defined in many ways, and disagreement remains regarding proper terminology and measurement methodology. Although the terms "post-harvest loss," "food loss," "food waste," and "food loss and waste" are frequently used interchangeably, they do not refer consistently to the same aspects of the problem. In addition, none of these classifications includes pre-harvest losses. Consequently, and despite the presumed importance of food loss, figures regarding food loss remain highly inconsistent, precise causes of food loss remain undetected, and success stories of decreasing food loss remain few. We improve over this measurement gap on food losses by developing and testing the methodology traditionally used with three new methodologies that aim to reduce the measurement error and that allow us to assess the magnitude of food loss. The methods account for losses from the pre-harvest stage through product distribution and include both quantity loss and quality deterioration. We apply the instrument to producers, middlemen, and processors in seven staple food value chains in five developing countries. Loss figures across all value chains fluctuate between 6 and 25 percent of total production and of the total produced value; these figures are consistently largest at the producer level and smallest at the middleman level. The identified losses are in addition to the existing yield gaps identified across the different commodities studied which are in the range of 50 to 80%. Throughout the different estimation methodologies, losses at the producer level represent between 60 and 80 percent of total value chain losses, while the average loss at the middleman and processor level lies around 7 and 19 percent, respectively. Differences across methodologies are salient, especially at the producer level. While the estimation results from the three new methods implemented are close and the differences are mostly not statistically significant, the aggregate self-reported method reports systematically lower loss figures. Finally, our results show the major reasons behind the losses identified for each commodity and country. Specifically, we find that they included pests and diseases and lack of rainfall. When looking at the produce left in the field, the major reason for the loss is a lack of appropriate harvesting techniques. Finally, the loss reported at the post-harvest level is due mostly to damage done during selection, as a result of workers' lack of training and experience in selecting the produce. Therefore, technology, improved seeds and the proper soil management techniques together with better market access could help to substantially reduce the losses at the producer level.

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Introduction

Food loss and food waste have become an increasingly important topic in the development community. In fact, the United Nations included the issue of food loss and waste in the Sustainable Development Goal target 12.3, which aims to "halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses" by 2030. Food loss and food waste have caught the attention of both researchers and policymakers for several reasons. First, growing populations and changing diets associated with greater wealth are increasing the pressure on the world's available land, constituting serious threats to food security, especially in developing countries. Policies to reverse this situation have mainly aimed at increasing agricultural yields and productivity, but these efforts are often cost- and time-intensive. Second, the loss of marketable food can reduce producers' income and increase consumers' expenses, likely having larger impacts on disadvantaged segments of the population. Third, food loss and waste entail unnecessary greenhouse gas emissions and excessive use of scarce resources.

Food loss and waste occurs at different stages of the food value chain (VC): production, post-production procedures, processing, distribution, and consumption (FAO, 2011; HLPE, 2014; Lipinski et al., 2013). Figure 1 shows the stages of the value chain at which food loss occurs, as well as the dimensions that are potentially responsible for loss at each stage. The distribution of loss and waste along the food chain is different depending on the commodity and the geographical location in question, but food loss and waste are commonly the result of underlying inefficient, unequal, and unsustainable food systems.

By reducing food loss and waste, we can improve food availability and food access without increasing the use of agricultural inputs, scarce natural resources, or improved technologies on the production side. Recent reports, however, highlight that success stories of decreasing food waste (WRAP, 2009) and food loss (World Bank, 2011) are not many, and figures on food loss and food waste remain highly inconsistent. Thus, while various governmental, research, and civil society initiatives have been launched to address this important issue, large results are yet to be seen.

The implementation of a strategy to reduce food loss faces three important challenges. First, no accurate information exists about the extent of the problem (especially in developing countries). The available estimates suggest that food loss is alarmingly high and may account for at least one-third of total global food production. For the most part, calculations of food loss hinge upon accounting exercises that use aggregate data from food balance sheets provided by national or local authorities. These "macro" estimations are subject to considerable measurement error, rely on poor quality data, or are not based on representative samples. Moreover, they only quantify the volume of food that is lost and do not take into account potential deterioration of quality or reductions of economic value that also affect farmers and consumers.

More recently, efforts have been made to use micro data to estimate food loss. These estimations rely on surveys collected among different actors across the food value chain. However, they tend to be based on case studies that are not representative of a country's larger populations. Additionally, these studies use different definitions of food loss, hampering comparisons across different areas and crops. Due to their lack of representativeness and differences in their methodologies, the available micro-based estimates are widely variable and yield inconclusive evidence about the extent of food loss.

The second challenge is the scarce evidence regarding the source of food loss. Food loss is associated with a wide array of factors (e.g., poor agricultural management skills and techniques, inadequate storage, deficient infrastructure, inefficient processing, lack of coordination in marketing systems, etc.) and can occur in different stages of the value chain (i.e., production, harvesting, post-production, processing, distribution, or consumption). Because of the aggregate nature of their data, macro studies are unable to capture the critical stages at which food loss occurs. Arguably due to the cost of primary data collection, most micro studies have not incorporated detailed information regarding sources of food loss in their survey instruments. Most of these studies aim to capture total food loss based on farmers' self-reported estimates but do not aim to disentangle the relevant production phases in which losses are generated. For example, studies using the nationally representative Living Standard Measurement Surveys – Integrated Surveys on Agriculture (LSMS – ISA) ask farmers to assess the proportion of their crops lost to rodents, pests, insects, flooding, rotting, theft, or other reasons; these studies can only provide global estimates. A few studies have collected more comprehensive information about the particular stages in which losses occur; however, these studies are based on small samples in particular locations, making their results difficult to extrapolate.

Third, there is little evidence regarding how to successfully reduce food loss across the value chain. There have been efforts to introduce particular technologies along specific stages of the value chain (e.g., silos for grain storage, triple bagging for cowpea storage, or mechanized harvesting and cleaning equipment for wheat and maize). However, little evidence exists regarding adoption rates or the economic sustainability of these efforts. In particular, there is a need to better understand how to introduce economic incentives for actors from farm-to-fork, taking into account the upstream and downstream linkages across the value chain.

This paper aims to resolve the first two challenges described above. Our objective is to improve how food loss is quantified[5] and characterize the nature of food loss across the value chain for different commodities in a wide array of countries[6]. For this purpose, we designed a set of surveys to measure the extent of food loss. While the surveys were tailored to specific countries and commodities and commodity varieties (for example, while Maize in Honduras and Guatemala have the same attributes, wheat in China has different attributes than what in Mexico), they provide a consistent measurement of food loss across different agents in the value chain (i.e., farmers, middlemen, and processors). The surveys capture detailed information about these agents' different processes and quantify food loss along each production stage by collecting self-reported measures of the volumes and values of food losses incurred during different processes (harvesting, threshing, milling, shelling, winnowing, drying, packaging, transporting, sorting, picking, transforming, etc.). In addition, we estimate losses based on commodity damage by collecting detailed data from farmers, middlemen, and processors regarding the quality (based on damage coefficients) of agricultural commodities that they use as inputs and outputs. This allows us to quantify food loss in terms of the quality attributable to each agent across the value chain. Finally, we also estimate food loss based on commodity attributes by capturing information about different types of commodity attributes (e.g., size, impurities, broken grain, etc.) and ascertaining the price penalty that each of these types of crop damage entails. In this line, we are able to identify particular factors that diminish commodities' values and thus are able to quantify food quality loss based on market conditions.

The surveys implemented allow us to quantify the extent of food loss across the value chain using consistent approaches that are comparable across commodities and regions. They also enable us to characterize the nature of food loss; specifically, we are able to ascertain the production stages across of the value chain and the particular processes in which losses are incurred. The results will therefore inform us about the particular areas that require investments to reduce food loss.

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[5] We follow de Mel et.al 2009 framework in the sense of exploring different ways to measure food losses so to reconcile how far we can reconcile self-reported food losses through more detail questions across the different stages of the value chain.

[6] It is important to mention that this paper does not measure food waste as Bellemare et.al 2017.

The paper is divided as follows. The first section looks at different issues regarding the definition of food loss across the value chain. We then conduct a review of the existing work on value chains and identify the major problems and gaps in the literature. In the third section, we present our methodological approach, followed by our key findings for Ethiopia, Ecuador, Honduras, Guatemala, and Peru. Finally, we examine the major reasons for the identified losses, using detailed regression analysis. The paper ends with conclusions and policy recommendations.

Divergence in terminology and definitions

The literature contains a common agreement regarding value chain stages (Figure 1), as well as agreement on the fact that food loss occurs at each stage (e.g., FAO, 2011; Lipinski et al., 2013; Parfitt, Barthel, and Macnaughton, 2010). However, no agreement exists regarding further classification of food loss and food waste. The terms 'Post-Harvest Losses' (PHL), 'Food Loss' (FL), 'Food Waste' (FW), and 'Food Loss and Waste' (FLW) are frequently used interchangeably, but they hardly ever refer consistently to the same concept. For some authors, the distinction is linked to the stages at which the loss occurs. For others, the distinction is based on the cause of the food loss and whether it was intentional. Some recent publications have tried to create more clarity (FAO, 2014; HLPE, 2014; Lipinski et al., 2013). In these studies, FL refers to unintentional reductions in food quantity or quality before consumption; these losses usually occur in the earlier stages of the food value chain, from production to distribution. PHL is a sub-section of FL, excluding losses at the production level (although losses during harvest are sometimes misleadingly included in the concept; e.g. Affognon, 2014; APHLIS, 2014). FW refers to food that is fit for human consumption but that is deliberately discarded; this is most common at the end of the value chain. The totality of losses and waste along the value chain with respect of total harvested production are encompassed in FLW (FAO, 2014); however, this definition does not include crops lost before harvest because of pests and diseases or left in the field, crops lost due to poor harvesting techniques or sharp price drops, or food that was not produced because of a lack of proper agricultural inputs. To include these pre-harvest losses, we propose a more expansive definition that will capture all losses across the value chain (see Figure 1). It is important to note that in this paper, we do not look at waste at the end of the value chain. This is because, from an integrated value chain perspective, pre-harvest conditions have direct impacts on eventual losses at later stages of the chain, due to products' different quality, storage- and shelf-life, and transport suitability.

There is also no agreement in the literature regarding the definition of food loss within each VC stage. To give just one example of differing definitions: losses across the value chain can originate from reductions in both food quantity and food quality and can thus describe either weight, caloric, nutritional, and/or economic losses. Due to estimation difficulties, product seasonality, and markets' sensitivity to food quality, most studies analyze quantitative losses, describing losses in terms of weight reductions (e.g., APHLIS, 2014; HLPE, 2014); these reductions sometimes translate into caloric terms (e.g. Kummu et al., 2012; Lipinski et al., 2013), but they still do not capture qualitative dimensions such as nutritional content and physical appearance (see Affognon et al. (2014) for a literature review). The choice of definition used depends on a stakeholders' priorities, as well as on the data available; however, that choice has important implications for the estimation methodology used to examine food loss, as well as on the interpretation of results.

Figure 1: Levels at which food loss occurs

PRODUCER 'ON – FARM' LOSS			MIDDLEMAN		PROCESSOR
Production →	**Post – harvest, on farm**	Sales →	**Post – harvest, off farm**	Sales →	**Transformation**
• Quantitative loss: Production 'left in the field' • Qualitative loss: Quality deterioration of harvested production	• Quantitative loss: Production totally lost during on-farm post-harvest activities • Qualitative loss: Quality deterioration during on-farm post-harvest activities		• Quantitative loss: Production totally lost during off-farm post-harvest activities • Qualitative loss: Quality deterioration during off-farm post-harvest activities		• Quantitative loss: Production totally lost during product transformation activities • Qualitative loss: Quality deterioration during product transformation activities

How loss has been measured

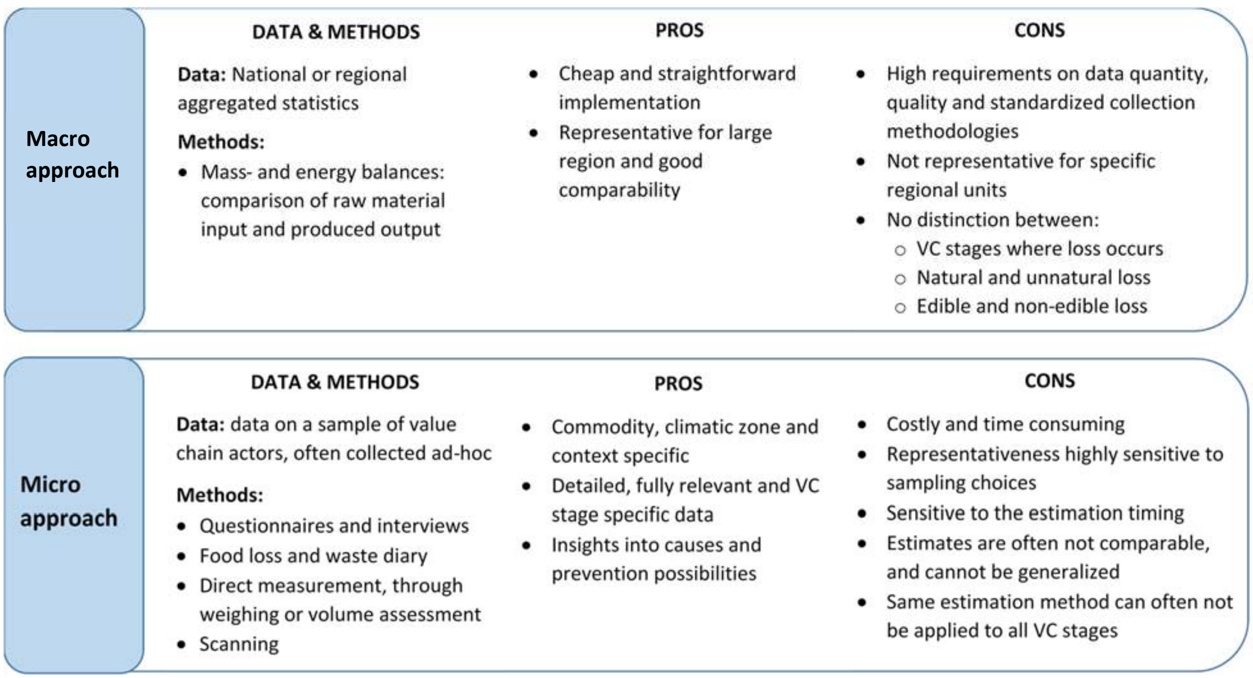
Two main estimation methodologies have been used to study food loss across the value chain: a macro approach, using aggregated data from national or local authorities and large companies, and a micro approach, using data regarding specific actors of the different value chain stages (Figure 2). The macro approach relies on mass or energy balances in which raw material inputs, in either weight or caloric terms, are compared to produce outputs. This method provides a cost-effective indication of the overall losses along the entire value chain and was used by Gustavsson et al. (FAO, 2011), the study that has been most quoted and used as a reference for food loss at the global level. By using FAO Stat's Food Balance Sheets, this study estimates that around 32 percent of global food production, across all production sectors, is lost along the entire food value chain. Kummu et al (2012) and Lipinski et al. (2013) use the same raw data and find that this translates into a 24 percent decrease in caloric terms. In country-specific studies, macro energy balances show that 48 percent of the total calories produced are lost across the whole food VC (Beretta et al. 2013; Switzerland), while mass balance data series from USDA data, using alternative assumptions, show that 28.7 percent of the harvested product is lost between post-production and consumption (Venkat et al., 2011; US) and that 31 percent of the available food supply is lost at distribution and consumption (Buzby et al. 2014, US). One disadvantage of this method is the demand for representative and good quality production, loss, and waste data. Data gaps are particularly apparent for certain regions of the world, such as low-and middle-income countries, and specific stages of the VC, such as primary production, processing, and retail (Stuart, 2009). The method is also not representative of smaller regional units, preventing identification of the value chain stages at which the losses occur; this challenges the appropriate targeting of loss reduction interventions. Finally, the aggregated data used for mass balances are often incapable of differentiating between natural loss (e.g., moisture loss) and unnatural weight loss, as well as edible and inedible loss.

The micro approach, on the other hand, uses sample data regarding specific value chain actors. Data are obtained through different methods: structured questionnaires and interviews, food loss and waste diaries compiled directly by the VC actor, direct measurements by the researcher, and food scanning methods, which can be used in developed retail markets. These methods are highly region- and context-specific, are more useful in disentangling the origin of loss along the value chain, and tend to provide more insights into causes and prevention possibilities. The most famous estimate for developing countries is given by the African Postharvest Losses Information System, which provides post-harvest weight loss estimates for cereal crops in Africa south of the Sahara (APHLIS, 2014). According to APHLIS, FL from production and post-production for cereals lies between 14.3 and 15.8 percent of total production. Kader (2009) reviews previous estimates of losses in both developing and developed countries and finds an average of 32 percent loss for fruits and vegetables. Official Eurostat data are used in the study by Monier et al. (2010) to quantify loss along different stages of the VC for 27 EU member states; by excluding waste at the agricultural production level, Eurostat estimates an annual average of 89 million tons of waste (i.e. 179 Kg per capita). A study by WRAP (2010) analyzes waste from the UK food and drink supply chain and finds that across processing, distribution, and consumption, 18.4 Mio tons of total food and drink are wasted annually in the UK; households are responsible for the largest share, wasting 22 percent of their purchases (WRAP, 2009).

The main challenges for the use of these micro methods to estimate food loss is cost and time to implement the studies, as well as the difficulty in getting a large enough proportion of responses to represent an entire VC or region. In addition, results are hard to compare because studies are adapted to their specific objective, focus only on specific stages of the VC, and use different data collection and estimation methodologies.

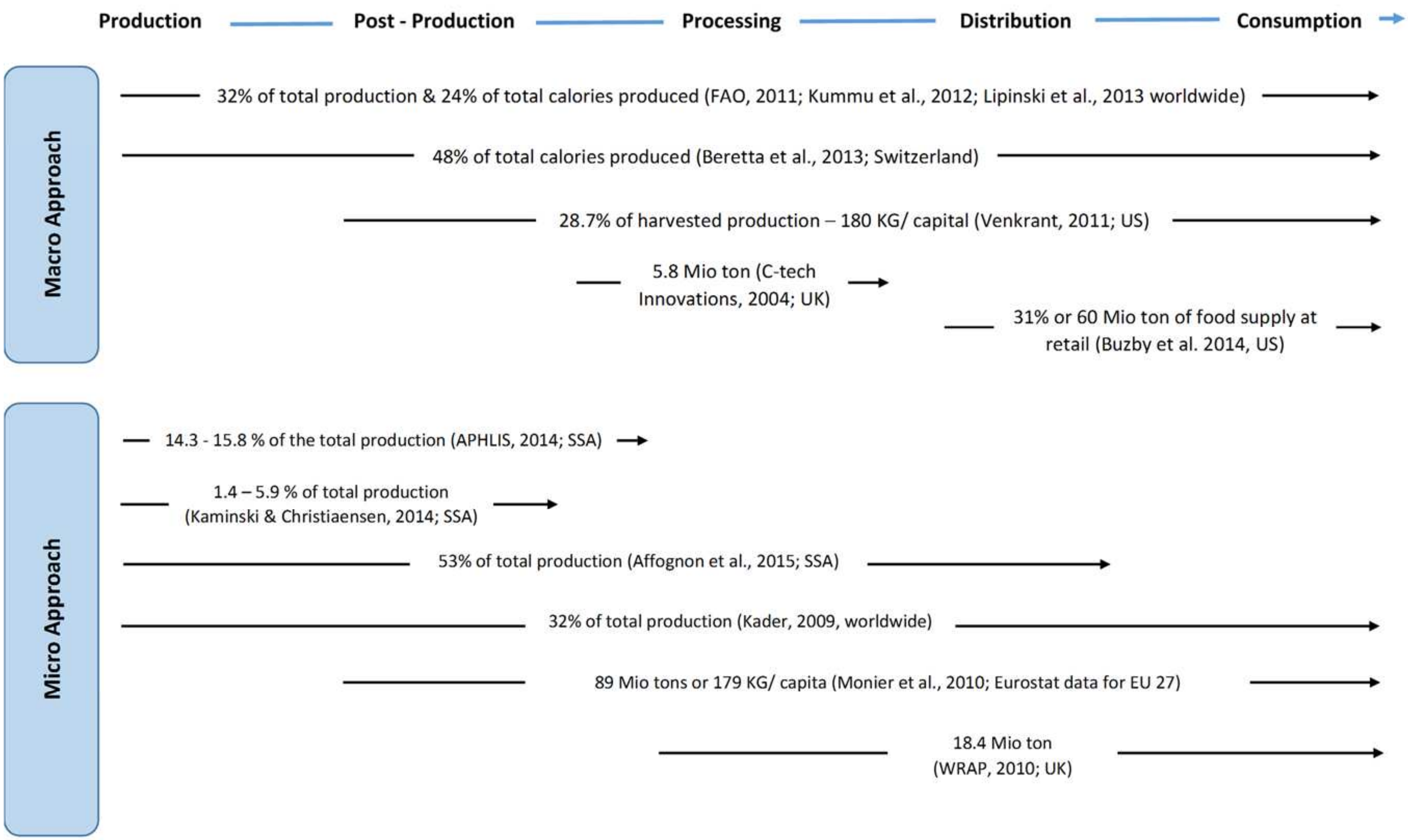
Figure 2 summarizes the two approaches to PFLW estimation, highlighting their advantages and drawbacks. Figure 3 provides an overview of global PFLW magnitudes from recent studies, distinguishing the two estimation approaches.[7]

Figure 2: PFWL estimation methodologies



[7] This does not intend to be a complete literature review, but merely provides reference on estimates from previous research. We selected studies encompassing more than one level and/ or commodity of the value chain. For a complete literature review, please see Affognon, 2015; Fusions, 2014; or Kader, 2009

Figure 3: Overview of global PFLW magnitudes from recent studies



All loss and waste is reported per year

Proposed approach

One main barrier to dealing with food loss and waste is the lack of clear knowledge regarding the magnitude of the problem (Lipinski et al., 2013). Uniform estimation methods to provide consistent loss figures are necessary, but they alone will not be sufficient to identify the underlying causes of and potential solutions to food loss or to outline priorities for action and monitor specific progress on loss reduction targets.

First, a standard definition and terminology for food loss and waste is crucially needed. This definition must adopt a value-chain approach, accounting for the fact that conditions at one stage of the chain likely affect losses and waste at later chain stages. Specifically, this definition needs to include pre-harvest losses, as their exclusion could lead to food loss and waste reduction interventions that do not tackle the source of the problem. This new definition must include both quantitative and qualitative reduction criteria, exclude natural, inedible, and unavoidable loss, and be able to be measured in economic, caloric, or quality-adjusted weight terms.

Second, loss assessment must prioritize analyses that identify the VC stages at which losses are created, rather than analyses that identify an exact overall figure. Loss measurement must also take into account the origin of food reductions along the value chain, as well as their geographical distribution.

We propose a developing country methodology that can measure losses at different stages of the value chain and that can be applied across crops and regions. Specifically, we propose three alternative methodologies against the mostly used methodology of *aggregate self-reported measures* of loss. The analysis will be limited to losses between the production and processing stages, as this is where inefficiencies are largest in developing countries. Information will be collected through representative surveys of farmers, middlemen, and transformers. These surveys will allow for the characterization of inputs, harvesting, storage, handling, and processing practices for each of these agents and will estimate the quantities, quality, and prices of the production as it travels along the value chain.

Our methodology captures both quantitative and qualitative losses, as well as discretionary losses among the processing, large distribution, and retail sectors. Food waste and household waste are more challenging to capture, and data need to be collected on representative samples. This will require the development of a widely `accepted sampling and measurement framework, which will likely be composed of a mixture of methods (e.g. waste composition analysis, questionnaires, interviews, or waste diaries; see WRAP, 2013). This paper does not look at food waste.

Methodology

We test different methodologies to estimate food loss along the value chain by drawing on the literature and economic theory. Our methodologies are applied to the producer and middleman level of the value chain to cover the main steps at which loss might occur. Due to the heterogeneity of the crop transformation processes at later steps in the value chain, at the wholesale level only the aggregate 'self-reported' food loss measurement method might be used. All methodologies estimate both the total food that is lost (quantitative loss) and the product that, albeit not being completely lost, is affected by quality deterioration (qualitative loss). The reference period is the last cropping season at the producer level; for the middlemen and the processors, it is a defined time-period (depending on the country).

Self-reported method

The aggregate 'self-reported method' (S-method) is based on reporting by the producers, middlemen, and processors regarding the food losses they each incurred. Self-reporting has been widely used in recent studies on food loss (e.g., Kaminski and Chistiaensen, 2014; Minten et al., 2016a; Minten et al., 2016b).

We use this method at the producer, middleman, and processor level. Direct survey questions inquire each actor about their quantitative and qualitative losses. At the producer level, the survey instrument includes questions about pre-harvest and post-harvest losses. Middlemen and processors are asked about losses at different stages of post-harvest activities and transformation processes. Table A1 in the appendix provides insights about the exact survey questions used in the three survey instruments. The responses to the questions are added up to obtain the total loss figures in weight and values at the level of the three value chain actors.

Category method

The 'category method' (C-method) is based on the evaluation of a crop and the classification of that crop into quality categories. The method builds on the 'Visual Scale Method', developed by Compton and Sherington (1999) to rapidly estimate quantitative and qualitative grain loss. The C-method classifies each product into its end use, i.e. suitable for export, the formal market, the informal market, animal feed, etc. Each category is associated with a crop damage coefficient, indicating the percentage of the crop that is damaged within each category. The categories are established prior to data collection in collaboration with commodity specialists, local experts and value chain actors and vary between four and six, according to the commodity and country. In addition, an extensive pilot was conducted to validate the categories. By means of the described categories and damage coefficients, farmers are asked to evaluate their production at harvest and after post-harvest activities, while middlemen are asked to evaluate their product at purchase and sales. Both farmers and middlemen indicate at which price they sell the produce in the different categories, as well as a sales' price for ideal produce in the high and low season. At the producer level, the quantitative and qualitative loss in weight and in value are given by eq. 1 and 2, respectively:

$$WeightLoss_P = \sum_{i=1}^{5} c_i * QC_{iPH} - (Q_{PH} - Q_{Prod}) \tag{1}$$

$$ValueLoss_P = \sum_{i=1}^{I} (\overline{p}_{ideal} - \overline{p}_{Ci}) * QC_{iPH} - (V_{PH} - V_{Prod}) \tag{2}$$

where c_i is the damage coefficient for category *i*, $\bar{p}_{ideal}$ is the sample average sales price for an ideal product[8], $\bar{p}_{Ci}$ is the sample average sales price for a product in category *i,* and QC_{iPH} is the quantity in each category after post-harvest. Q_{PH} and V_{PH} are respectively the quantity and value of all produce after post-harvest, while Q_{Prod} and V_{Prod} are the quantity and value of all produce after production. The difference in quantities or values (the second terms of equation 1 and 2) provide us with the total quantity or value lost between production and post-harvest activities.

[8] Average across the low and high season

At the middleman level, the quantitative and qualitative loss in weight and in value are given by eq. 3 and 4, respectively:

$$WeightLoss_M = \sum_{i=1}^{I} c_i (QC_{iSale} - QC_{iPurchase}) + WeightTotLost \quad (3)$$

$$ValueLoss_M = \sum_{i=1}^{I} (\bar{p}_{ideal} - \bar{p}_{Ci}) * (QC_{iSale} - QC_{iPurchase}) + ValueTotLost \quad (4)$$

where c_i is the same damage coefficient as in the producers' survey. $\bar{p}_{ideal}$ and $\bar{p}_{Ci}$ are the average sale price for an ideal product and sale price for a product in category *i* at the middlemen level. QC_{iSale} and $QC_{iPurchase}$ are the quantities in each category at purchase and at sale. To get the full quantitative and qualitative loss measure, we add the weight (or value) of the quantity that was totally lost, i.e. disappeared from the value chain. This figure is ideally obtained from the difference between the total purchase and total sales within a given period of time. Practically, middlemen are often unable to indicate these exact quantities, as the purchased crop is mixed with product in storage. We therefore use the information from the direct survey question on the weight and value totally lost at the middleman level, i.e. product that completely disappeared from the value chain.

Attribute method

The 'attribute method' (A-method) is based on the evaluation of a crop according to inferior visual, tactile, and olfactory product characteristics. These attributes are identified prior to the survey implementation and in collaboration with commodity experts, local experts and value chain actors. In addition, an extensive pilot was implemented to validate the attributes[9]. The number of attributes varies between 10 and 14, according to the commodity and country. At the time of the survey, the producer evaluates his or her production and establishes the share of total production that is affected by the attributes, both after harvest and after post-harvest. Middlemen evaluate their product from the previous month at both purchase and sale. The producer and the middlemen declare how much their respective buyers punish them for inferior product attributes by paying a lower price. The price punishment information for each product attribute is used to estimate the value loss. At the producer level, the quantitative and qualitative loss in weight and in value are given by eq. 5 and 6, respectively:

$$WeightLoss_P = \sum_{j=1}^{J} a_j * Q_{PH} - (Q_{PH} - Q_{Prod}) \quad (5)$$

$$ValueLoss_P = \sum_{j=1}^{J} \overline{pa}_j * Q_{PH} - (V_{PH} - V_{Prod}) \quad (6)$$

where a_j is the share of product affected by attribute j, and $\overline{pa}_j$ is the average price punishment for an inferior product attribute at sale. As before, Q_{PH} and V_{PH} are respectively the quantity and value of all produce after post-harvest, while Q_{Prod} and V_{Prod} are the quantity and value of all produce after production. While the first terms of equations 5 and 6 provide us with the quantity affected by a loss (qualitative loss),

[9] Is important to mention that in certain countries the attributes are defined as legal standards for the specific commodity.

the second terms provide us with the total quantity or value lost (quantitative loss) between production and post-harvest activities.

At the middleman level, the quantitative and qualitative loss in weight and in value are given by eq. 7 and 8, respectively:

$$WeightLoss_M = \sum_{j=1}^{I}(Q_{Sale,a_j} - Q_{Purchase,a_j}) + WeightTotLost \quad (7)$$

$$ValueLoss_M = \sum_{j=1}^{I}(V_{Sale,a_j} - V_{Purchase,a_j}) + ValueTotLost \quad (8)$$

where $Q_{Sale,aj}$ and $Q_{Purchase,aj}$ are the quantities sold and purchased with a certain damage attribute. $V_{Sale,aj}$ and $V_{Purchase,aj}$ are the values at sales and purchase that are lost due to a damage attribute; they are obtained by multiplying the previous quantities by the average price punishment. $QC_{iPurchase}$ are the quantities in each category at purchase and at sale. The weight (or value) of the quantity that was totally lost, i.e. disappeared from the value chain, provides us with the full quantitative and qualitative loss measure.

Price method

The 'price method' (P-method) is based on the reasoning that higher (lower) values of a commodity reflect higher (lower) quality. A decrease in price, all else equal, is thus a proxy for a deterioration in quality. Data regarding producers' and middlemen's ideal sale value are used and compared to the value of their actual production, purchase, and sales. The following equations provide us with the total loss at the producer level:

$$ValueLoss_P = V_{ideal} - V_{PH} \quad (9)$$

where V_{ideal} is obtained by the multiplying the farmers' production by the average ideal sales' price; V_{PH} is the total value of the farmers' production after post-harvest, as assessed by the farmer himself. The value loss can be translated into a weight loss by dividing it by the ideal sales price:

$$WeightLoss_P = \frac{ValueLoss_P}{\overline{p}_{ideal}} \quad (10)$$

For the middlemen, we take the difference between the value (or weight) affected by loss at sales and the value (weight) affected by loss at purchase to estimate the total value (weight) affected by loss at this level of the chain. The value (or weight) affected by the loss at purchase or sale is estimated by taking the difference between the sale (purchase) value of an ideal product and the actual sale (purchase) value. We add the weight (or value) of the quantity that was totally lost, i.e. disappeared from the value chain, to get the full quantitative and qualitative loss measure. This translates in the following two equations:

$$ValueLoss_M = (V_{Sale;ideal} - V_{Sale;actual}) - (V_{Purchase;ideal} - V_{Purchase;actual}) + ValueTotLost \quad (11)$$

$$WeightLoss_M = (Q_{Sale;ideal} - Q_{Sale;actual}) - (Q_{Purchase;ideal} - Q_{Purchase;actual}) + WeightTotLost \quad (12)$$

Data

As mentioned in our literature review, there have recently been efforts to use micro data to estimate food loss. These estimations rely on surveys collected among different actors along the food value chain; however, they are based on case studies that are not representative of a country's broader population. Additionally, these studies use different definitions of food loss, which hampers comparisons across different areas and crops. Due to this lack of representativeness, as well as to differences in their methodologies, available micro-based food loss estimates are widely variable and yield inconclusive evidence regarding the extent of food loss.

We have developed detailed surveys across the different components of the food value chain and specific to different commodities. These surveys allow us to quantify the extent of food loss across the value chain using *consistent* approaches that are comparable across commodities and regions. They also enable us to characterize the nature of food loss, specifically the production stages and the particular processes at which loss is incurred.

Our survey instruments quantify food loss along the value chain before consumption (food waste by consumers is excluded from the calculations). The richness of the data allows us to provide estimates using alternative methodologies. We first calculate *aggregate self-reported measures* of loss: we ask farmers, middlemen, and processors about the quantities (and the corresponding monetary values) of crops discarded during the processes that they perform (e.g., winnowing, threshing, grading, transporting, packaging, etc.). This methodology is, in general, consistent with the basic elements in the available literature on the measurement of food loss. Our surveys, however, include a more disaggregated description of the stages and processes at which loss occurs. The producer, middlemen, and processor surveys were designed to have different modules to measure loss across the value chain.

The producer survey has three modules. The first module asks about the quantity of the crop left in the field, the total production harvested, and the qualities, attributes, and prices of the harvest. The second module asks about the post-harvest activities conducted by the producers (e.g., winnowing, threshing, grading, transporting, packaging, etc.); for each of these activities, the producer is asked for the quantity of affected product [10] and the quantity totally lost. [11] The third module records the destination of the product (i.e for consumption, for sale, for donation, etc.), as well as the attributes and categories for the quantity for sale.

The middlemen survey has three modules. The first module asks about the quantity, quality, and attributes of the total product purchased in a defined time-period (depending on the country). The second module asks middlemen to report the quantity, quality, and other attributes of the total product sold in a defined time-period (depending on the country). The third module asks questions about the post-harvest processing activities conducted by the middlemen (e.g., winnowing, threshing, grading, transporting,

[10] Affected product: Product that lowers quality but can still be used.
[11] Totally lost: Product that is completely lost and cannot be used

packaging, etc.); in each of these activities, the quantity of affected product and the quantity of total loss are reported for each crop.

The processor survey has two modules. The first module asks for the quantity, quality, and attributes of the total product purchased in a specific time-period (depending on the country). The second module asks about the specific steps required to obtain the final product for consumer consumption.

Within each survey, we categorize the crop damage and crop attributes of each crop and country. In order to categorize the damage for each crop, we created a damage coefficient. The damage coefficient is measured by categorizing the total amount of each crop into degrees of quality. In our surveys, each crop has its own damage coefficient, which were made using the international classification in collaboration with local experts. For maize and beans in Honduras and Guatemala, there are five categories, with category 1 classified as having 1-2 percent of damaged grain (grain with no problems), and category 5 classified as having more than 25 percent of damaged grain (grain that is unusable). In Ethiopia the five categories range from category 1 (undamaged grain) to category 5 (more than 80 percent of damaged grain). In Ecuador and Peru, the categories are related to the caliber[12] of the tuber; crops categorized as caliber 1 have a diameter bigger than 10 cm (Category Extra), while category 5 consists of tubers with a diameter around 6cm, which is used to feed animals.

The attributes section of the survey evaluates the crops according to physical or chemical characteristics to see if they have inferior visual, tactile, and olfactory characteristics. These characteristics are specific to each country and crop. In our surveys, we measure the damage of each crop by texture, size, moisture, and the presence of fungus or insects, etc. These attribute categories were created with the collaboration of local experts.

One drawback to this first aggregate self-reported method is that it is reported by the farmers in a more 'aggregate way' through a direct question (see appendix table A1) not allowing to identify where in the value chain the losses occur and not allowing to differentiate what is quantity and what is quality loss. While food is not necessarily discarded completely along different processes, quality downgrades at different stages of the value chain can affect food's economic value. Our survey instruments improve upon these traditional measures by allowing us to quantify qualitative loss using two alternative methods. First, we estimate the shares of total food production at each stage of the value chain that were damaged and are subject to qualitative loss (based on *damage coefficients*). Second, we collect information about different types of commodity attributes (e.g., size, impurities, discoloration, etc.) and ascertain the price penalty that each of these types of crop damage entails (i.e., *attribute penalties*). We are thus able to identify specific factors that diminish commodities' values and to quantify food quality losses based on market conditions.

[12]Caliber: Size of internal diameter of the tuber

Value chains and descriptive statistics

In order to meet the objectives of this project, the sample must be large enough to provide reliable estimates for most of the indicators at the producer, middleman, or processor level.

For all countries, we chose our sample based on a pre-census of the producers of the specific crop of interest. This is our baseline. Selected producers must have produced crops in the last season.

Potatoes are essential to the Ecuadorian diet, with each person consuming around 30 kg per year (MAGAP,2014). The crop occupies the tenth place among the most consumed products by the Ecuadorian population and is one of the top eight most produced crops. Ecuador produces 397,521 tons of potatoes annually, with the province of Carchi producing 36.48 percent of the national volume (ESPAC, 2015).

Our surveys in Ecuador were organized between June and October 2016 for each segment of the potato value chain. All producers in the survey came from the province of El Carchi, while the middlemen were from the provinces of El Carchi, Imbabura, and Pichincha and the processors were from the province of Pichincha.

Potatoes have also been essential to the diet of Peruvians for millennia. Peru's annual consumption of potatoes is around 89 kg per person (MINAGRI, 2016). The crop occupies second place for the most cultivated crop area in Peru, with 318,380 hectares planted to potato and 4,704,987 metric tons of potatoes produced in 2014 (FAOSTAT). The two principal providers of potatoes to the Lima market are the departments of Junín and Ayacucho, which provide around 60 percent of the potatoes that go to the wholesale market (EMMSA).

Our surveys in Peru were organized between September and December 2016 for each segment of the potato value chain. The producers in the survey were from the departments of Junín and Ayacucho, while the middlemen and processors were from the department of Lima.

For the Central American region, maize and bean crops are staples for a variety of reasons. These crops form the fundamental basis of food security for much of the population, and they contribute to household and national economies through employment generation and income generation (IICA, 2014).

In Honduras, maize is one of the most important basic grains, but the domestic maize supply only covers 42 percent of the country's demand (SAG/UPEG, 2015). The annual consumption of maize in Honduras in 2013 was around 77.96 kg per person, while the production of maize in 2014 was 609,312 metric tons over an area of 263,343 hectares (FAOSTAT). The three principal production departments of white maize in Honduras are Olancho, El Paraíso, and Comayagua.

Beans are the second most important basic grain in Honduras, both in area planted and in production for consumption. In 2014, the annual consumption of beans in Honduras was 12.05 kg per person, and an average of 132,659 hectares were planted with beans. Bean production in 2014 was 105,812 metric tons (FAOSTAT). The three principal production departments for beans in Honduras are Olancho, El Paraíso, and Yoro.

Our surveys for Honduras were organized between July and September 2016 for each segment of the maize and bean value chains. The producers, middlemen, and processors in the survey were from the departments of Choluteca, Copan, El Paraiso, Francisco Morazan, Intibuca, La Paz, Lempira, Ocotepeque, Olancho, Santa Barbara, and Valle.

In Guatemala, maize is the most widely cultivated crop and is one of the most valuable and rooted symbols of Guatemalan culture. In 2014, the area cultivated to maize was 871,593 hectares, with a production of 1,847,214 metric tons. Per capita consumption for 2013 was around 87.25 kg per person per year (FAOSTAT). The three principal production departments of white maize in Guatemala are Peten (18.5 percent), Alta Verapaz (9.4 percent), and Jutiapa (7.3 percent) (MAGA, 2016).

Beans are the second most important basic grain in Guatemala, both in area planted and in production for consumption. In 2014, the consumption of beans in Guatemala was 12.12 kg per person per year; area planted to beans covered an average of 250,414 hectares, with production at 235,029 metric tons (FAOSTAT). The three principal production departments for beans in Guatemala are Peten (27 percent), Jutiapa (13 percent), and Chiquimula (10 percent) (MAGA, 2016).

Our surveys in Guatemala were organized between September and December 2016 for each segment of the maize and bean value chains. The producers, middlemen, and processors were from the departments of Chimaltenango, Escuintla, Guatemala, Quetzaltenango, Sacatepequez, San Marcos, Solola, and Totonicapan.

Teff constitutes a major crop in Ethiopia, in terms of both production and consumption. Teff is the dominant cereal crop for total area planted (3,760,000 hectares in 2012/2013; FAS, 2014) and second in production and consumption, with 3,769,000 metric tons (Berhane, Paulos, Tafere and Tamru, 2011; Ethiopian Agricultural Transformation Agency [EATA], 2013). According to Berhane, et al. (2011), based on national data from the Household Income, Consumption and Expenditure Survey (HICES, 2011), in 2001-2007, urban consumption of teff per capita was as high as 61 kg per year, while rural consumption was 20 kg per capita per year. Teff is grown mainly in Amhara and Oromiya, which together accounted for 84 and 86 percent of the total cultivated area and production in 2011.

Our surveys in Ethiopia were organized between August and October 2016 for the producer chain only, from the zones of Oromia and Amhara given that in the case of this commodity there are no important intermediaries and processors.

We adapted our instrument for the specifications of each crop and country. For example, in Ecuador and Peru, we work with potato value chains; in these cases, the instrument has six different categories and nine different attributes. In Guatemala and Honduras, where we work with the maize and bean value chains, the instrument has five different categories and 12 different attributes. Finally, in Ethiopia, we work with the teff value chain, in which the instrument has five different categories and 12 different attributes.

The formula used for calculating the representative random sample for all the countries is:

$$n = \frac{N \cdot Z^2 \cdot p \cdot (1-p)}{(N-1) \cdot e^2 + Z^2 \cdot p \cdot (1-p)} \qquad (13)$$

In a stratified random set-up, we sampled a moderate number of actors per segment in each country. At the end, the sample consisted of:

Table 1: Sample size

	Ecuador	Peru	Honduras	Guatemala	Ethiopia
Producer	302	411	1209	1155	1203
Middlemen	182	85	325	365	---
Processor	147	139	224	245	---
Total	**631**	**594**	**1758**	**1765**	**1203**

Tables 2-4 provide descriptive statistics of the sample of each different crop in each country for producers, middlemen, and processors, respectively.

In Table 2, we can see that for all countries, the majority of producers are male and have reached at least a primary level of education. Teff producers from Ethiopia are the youngest on average, while Guatemalan maize producers are the oldest and have the most years of experience working with their crop. More than 65 percent of producers from Peru, Ecuador, and Ethiopia used improved seeds in the last crop season (for potato and Teff, respectively); less than 20 percent of maize and beans producers from Guatemala and Honduras used improved seed. Potatoes in Peru and Ecuador were stored for shorter periods of time compared to the storage of grains in all the other countries.

In Table 3, we can see that for all countries, around 60 percent of middlemen are male, with an average age between 40 and 50 years. The average number of years that middlemen have been in business is higher for middlemen buying and selling potatoes in Ecuador and Peru than for middlemen buying and selling maize and beans in Guatemala and Honduras.

Across all countries, middlemen purchased more commodities from producers than from other middlemen. This could be due to the fact that prices from producers may be cheaper and producers may be more likely to seek out middlemen in the big cities.

In Table 4, we can see that the majority of processors in Peru and Ecuador are male, and the main products traded are French fries. In Honduras and Guatemala, the majority of processors are female, and the main products traded are maize tortillas and packaged beans. For all countries, the average age of processors is 40 years.

In Peru and Ecuador, all of the potato processors' businesses are formal (legal), but for maize and bean processors from Guatemala and Honduras, somewhat less than 40 and 60 percent, respectively, are informal.

All countries, with the exception of Honduras, saw processors who purchased more from other middlemen than from producers.

Table 2: Producer characteristics

	Variable name		Ecuador: potato (N = 302)		Peru: potato (N = 411)		Guatemala: beans (N = 450)		Guatemala: maize (N = 922)		Honduras: beans (N = 685)		Honduras: maize (N = 1024)		Ethiopia: teff (N = 1203)	
			mean	std dev	mean	std dev	mean	std dev	mean	std dev	mean	std dev	mean	std dev	mean	std dev
Socio-economic characteristics	Gender (male)		92.72%	0.26	80.05%	0.40	87.56%	0.33	87.31%	0.33	95.04%	0.22	95.02%	0.22	94.18%	0.23
	Age (years)		50.15	13.97	44.36	14.02	48.75	15.03	50.23	15.01	47.78	14.47	48.52	15.07	44.21	11.43
	Education	no education	2.65%	0.16	3.41%	0.18	29.11%	0.45	30.91%	0.46	17.23%	0.38	19.14%	0.39	36.99%	0.48
		primary	73.18%	0.44	37.47%	0.48	64.89%	0.48	58.79%	0.49	79.56%	0.40	77.64%	0.42	39.32%	0.49
		secondary	11.92%	0.32	48.42%	0.50	3.78%	0.19	4.23%	0.20	2.34%	0.15	2.34%	0.15	20.20%	0.40
		>secondary	12.25%	0.33	10.71%	0.31	2.22%	0.15	6.07%	0.24	0.88%	0.09	0.88%	0.09	0.25%	0.05
	Household size		4.00	1.61	3.70	1.46	6.11	2.62	5.84	2.77	5.03	2.12	5.08	2.38	6.11	2.12
	Main income from agriculture (dummy)		56.95%	0.50	94.16%	0.23	*na*		*na*		*na*		*na*		*na*	
	Experience in cultivating crop (years)		24.06	13.80	16.95	12.87	22.53	15.17	25.29	16.23	26.37	15.16	27.03	16.21	22.09	10.99
Market access	Cost to reach market (USD/ Kg)		2.49	2.79	0.05	0.04	1.38	1.11	1.00	0.91	0.02	0.03	0.02	0.03	*na*	
	Time to reach market (hours)		0.81	0.31	0.96	0.61	1.38	1.11	1.00	0.90	3.28	3.34	3.59	3.78	4.05	2.88
Production	Quantity produced last harvest (Kg)		108,030	232,696	70,310	301,281	319	562	2251	3918	1384	2577	4953	31696	1479	1405
	Area cultivated (in hectares)		3.48	5.91	2.82	7.78	0.35	0.76	2.09	47.59	1.09	1.47	1.45	3.14	1.23	1.13
	Improved seeds (dummy)		15.56%	0.36	43.55%	0.50	3.78%	0.19	17.68%	0.38	8.91%	0.29	19.43%	0.40	73.90%	0.44
	Resistant variety (dummy)		29.14%	0.46	48.91%	0.50	*na*		*na*						13.05%	0.34
	Time of planting: primera vs postrera		*na*		*na*		74.89%	0.43	95.77%	0.20	33.43%	0.47	69.34%	0.46	*na*	
	Number of different inputs applied[a]		3.03	0.30	3.06	0.25	1.72	1.05	2.03	1.06	2.72	1.20	2.94	0.91	2.82	0.86
	Number of different field maintenance activities[b]		0.77	0.77	1.31	0.74	0.04	0.20	0.06	0.24	0.10	0.30	0.10	0.31	*na*	
	Number of mechanic production activities[c]		0.79	0.53	1.25	1.15	0.05	0.39	0.20	0.75	0.32	0.78	0.41	1.06	0.06	0.24
	Harvest technique	azadon'			91.48%	0.28										
		tractor	*no variation*		5.35%	0.23					*no variation*					
		lampa'			3.16%	0.18										
	Hired labor (dummy)		94.37%	0.23	88.32%	0.32	37.11%	0.48	70.39%	0.46	93.87%	0.24	94.92%	0.22	56.86%	0.50
Post-harvest[f]	Nb of post-harvest activities[d]		2.36	0.78	1.56	1.39	3.88	0.66	3.60	0.90	3.69	0.83	3.58	0.92	8.84	0.40
	Mechanical drying and winnowing			*na*			1.78%	0.13	4.88%	0.22	3.65%	0.19	5.27%	0.22	*na*	
	Mechanical threshing activity						*na*		*na*		6.19%	0.24	16.87%	0.37		
	Mechanical transport		25.50%	0.44	54.26%	0.50	15.56%	0.36	27.87%	0.45	22.53%	0.42	25.20%	0.43	0.00%	
	Storage (dummy)		6.62%	0.25	27.01%	0.44	98.89%	0.10	98.59%	0.12	89.34%	0.31	91.60%	0.28	98.25%	0.13
	Storage time (in months)		15.05	16.38	26.49	41.68	187.33	104.89	215.80	91.36	146.10	85.05	150.72	76.16	115.9594	68.60445
	Storage location	Silo	0.00%		0.00%		3.15%	0.17	0.00%		9.97%	0.30	52.77%	0.50	0.25%	0.05
		Granary	30.00%	0.47	40.54%	0.49	1.35%	0.12	9.13%	0.29	4.25%	0.20	4.58%	0.21	21.07%	0.41
		House (bag)	70.00%	0.47	59.46%	0.49	95.51%	0.21	90.87%	0.29	85.46%	0.35	42.64%	0.49	61.59%	0.49
		Trad Pit						*na*							5.84%	0.23
		Trad dibignet													11.17%	0.32
	Number of storage conservation activities[e]		0.55	0.60	0.77	0.70	0.41	0.57	0.47	0.51	0.68	0.47	0.78	0.43	1.65	0.69
Sales	Percentage sold (versus own consumption, barter, animals or seeds)		81.04%	0.17	84.23%	0.16	31.45%	0.25	21.40%	0.22	39.71%	0.32	25.57%	0.27	36.09%	0.25
	Sale location[g]	house or plot	16.56%	0.37	45.74%	0.50	63.33%	0.48	72.34%	0.45	86.05%	0.35	88.51%	0.32	3.85%	0.19
		nearest town	74.50%	0.44	27.74%	0.45	6.00%	0.24	22.99%	0.42	2.13%	0.14	1.99%	0.14	50.89%	0.50
		village market	9.27%	0.29	34.06%	0.47	25.78%	0.44	6.62%	0.25	12.21%	0.33	8.09%	0.27	48.17%	0.50
	Type of buyer the farmers sells to[g]	middlemen	68.87%	0.46	61.56%	0.49	4.89%	0.22	6.29%	0.24	54.84%	0.50	29.07%	0.45	61.13%	0.49
		wholesaler	30.46%	0.46	45.01%	0.50	21.11%	0.41	14.53%	0.35	17.25%	0.38	11.61%	0.32	19.15%	0.39
		processor	0.99%	0.10	1.46%	0.12	0.89%	0.09	3.36%	0.18	0.00%		2.81%	0.17	0.75%	0.09
		consumer	1.32%	0.11	8.03%	0.27	65.56%	0.48	76.14%	0.43	30.62%	0.46	59.44%	0.49	21.31%	0.41
	Number of transactions to sell last		1.52	1.94	3.02	4.34	1.97	3.30	2.03	6.56	1.26	1.28	1.39	3.49	2.15	1.63

Note: [a] This includes fertilizers, insecticides, herbicides and fungicides; [b] This includes activities such as irrigation, trimming, pruning; [c] Machine driven, instead of manual, include activities such as soil preparation, sowing, pest control, fertilizer application, weeding, 'aporque', 'corte del yuyo', harvest; [d] This includes activities such as selection, classification, drying etc; [e] This includes activities such as chemical fumigation, natural fumigation and ventilation; [f] storage summary statistics are obtained from the restricted sample of farmers storing the grains; [g] These variables are not mutually exclusive, as farmers can have more than one sales' location and type of buyer. The official exchange rate in the year of the survey are 0.04492 USD/ Birr; 0.1305 USD/ Quetzal; 0.0411 USD/ Lempiras; 0.297 USD/ Soles (www.oanda.com)

Table 3: Middleman characteristics

Variable name		Ecuador: potato (N = 182)		Peru: potato (N = 85)		Guatemala: beans (N = 169)		Guatemala: maize (N = 156)		Honduras: beans (N = 248)		Honduras: maize (N = 129)	
		mean	std dev	mean	std dev	mean	std dev	mean	std dev	mean	std dev	mean	std dev
Gender (male)		56.59%	0.50	57.65%	0.50	55.62%	0.50	69.23%	0.46	56.45%	0.50	60.47%	0.49
Age (years)		48.85	11.19	45.66	10.33	42.04	13.34	45.38	14.41	44.34	13.41	46.30	13.23
Experience in business		17.91	11.64	18.26	11.09	10.15	9.05	7.94	9.43	12.27	11.84	9.20	9.70
Formal business (dummy)		67.03%	0.47	94.12%	0.24	160.36%	0.49	153.21%	0.50	114.11%	0.35	113.18%	0.34
Type of business	intermediary	56.59%	0.50	0.00%	0.00	4.14%	0.20	3.21%	0.18	7.26%	0.26	13.95%	0.35
	wholesaler	30.77%	0.46	97.65%	0.15	95.86%	0.20	96.79%	0.18	92.74%	0.26	86.05%	0.35
	retailer	12.64%	0.33	2.35%	0.15								
Quantity purchased last month (Kg)		99,115	140,230	376,802	556,866	426	1,326	2,786	5,132	1,121	2,854	7,291	22,222
Value purchased last month (USD)		32,591	47,920	90,913	141,524	540	1,574	1,122	3,039	1,001	2,460	4,622	21,006
Average quantity purchased per day (Kg)		5,912	7,636	15,994	25,721	17	50	135	333	117	503	361	991
Average value purchased per day (USD)		1,982	2,659	3,855	6,195	18	53	36	77	49	166	120	291
Quantity purchased from different sellers (Kg)	producers	107,692	144,592	358,035	563,407	5.08	6.67	12.93	50.67	45.11	109.16	38.37	155.76
	middlemen	41,382	45,938	18,766	75,283	10.27	31.97	48.38	105.82	17.05	27.39	122.05	434.82
Quantity sold last month (Kg)		97,026	139,241	369,566	557,924	297	833	1,962	3,493	953	2,824	5,851	21,026
Value sold last month (USD)		32,591	47,920	90,913	141,524	540	1,574	1,122	3,039	1,001	2,460	4,622	21,006
Average quantity sold per day (Kg)		4,673	5,852	14,324	19,900	44	302	75	146	432	3,829	221	700
Average value sold per day (USD)		1,708	2,238	4,205	8,082	23	59	27	53	57	170	91	242
Price paid for 1 Kg of best quality product (USD)	abundance	12.66	4.17	0.19	0.09	49.75	8.70	15.69	3.02	36.20	10.37	14.32	4.49
	scarcity	20.68	4.20	0.52	0.18	67.71	13.27	21.70	23.81	63.47	19.37	21.86	3.85
Price received for 1 Kg of best quality product (USD)	abundance	13.63	4.61	0.19	0.09	62.34	10.24	16.41	3.41	43.33	24.95	14.51	4.99
	scarcity	22.12	4.08	0.53	0.20	73.75	20.94	19.98	4.64	63.70	23.69	21.36	5.23
Number of different buyers last month		74	151	154	265	31	35	26	64	4	10	2	9
Type of buyers sold to	wholesaler / intermediary	38.46%	0.49	30.59%	0.46	1.78%	0.13	8.97%	0.29	4.03%	0.20	8.53%	0.28
	retailer	78.57%	0.41	90.59%	0.29	0.59%	0.08	3.85%	0.19	2.42%	0.15	4.65%	0.21
	transformer	43.96%	0.50	16.47%	0.37	3.55%	0.19	14.10%	0.35	2.82%	0.17	6.98%	0.26
	end consumer	56.04%	0.50	28.24%	0.45	94.67%	0.23	94.23%	0.23	95.56%	0.21	89.92%	0.30
Type of transformation activities	drying	3.30%	0.18	0.00%	0.00	0.00%	0.00	4.49%	0.21	3.23%	0.18	3.88%	0.19
	selection	41.76%	0.49	41.18%	0.50	33.73%	0.47	25.00%	0.43	24.19%	0.43	22.48%	0.42
	storage	43.41%	0.50	23.53%	0.43	86.98%	0.34	72.44%	0.45	39.11%	0.49	46.51%	0.50
	transport	47.25%	0.50	4.71%	0.21	6.51%	0.25	19.87%	0.40	7.66%	0.27	17.83%	0.38

Note: The official exchange rate in the year of the survey are 0.04492 USD/ Birr; 0.1305 USD/ Quetzal; 0.0411 USD/ Lempiras; 0.297 USD/ Soles (www.oanda.com)

Table 4: Processor characteristics

Variable name		Ecuador: potato (N = 182)		Peru: potato (N = 153)		Guatemala: beans (N = 120)		Guatemala: maize (N = 104)		Honduras: beans (N = 121)		Honduras: maize (N = 124)	
		mean	std dev	mean	std dev	mean	std dev	mean	std dev	mean	std dev	mean	std dev
Gender (male)		53.06%	0.50	80.39%	0.40	19.17%	0.40	12.50%	0.33	15.70%	0.37	8.87%	0.29
Age (years)		43.93	13.15	42.16	10.14	41.55	11.82	38.94	11.74	44.17	12.83	46.36	13.53
Experience in business		10.15	13.37	10.41	10.80	13.13	9.13	6.88	8.45	11.88	12.99	15.40	11.12
Formal business (dummy)		100.00%	0.00	100.00%	0.00	45.00%	0.50	39.42%	0.49	62.81%	0.49	22.58%	0.42
Quantity purchased last month (Kg)		1,871	2,458	2,987	4,867	232	729	925	446	122	294	4,695	24,584
Value purchased last month (USD)		852	1,209	5,259	7,035	244	697	371	175	100	241	1,351	6,503
Average quantity purchased per day (Kg)		126.48	227.71	130.34	470.04	7.43	22.11	166.39	627.90	16.33	58.71	201.65	859.42
Average value purchased per day (USD)		72.00	226.59	247.42	1078.29	8.19	22.68	12.11	6.16	7.27	17.85	45.36	215.22
Number of different sellers last month		1.76	1.37	1.81	2.09	1.27	0.69	1.57	1.63	2.69	14.22	1.67	3.40
Price paid for 1 Kg of best quality product (USD)	abundance	17.70	4.55	1.58	0.50	54.54	11.57	16.85	3.16	36.88	7.25	15.08	5.25
	scarcity	23.82	5.42	2.93	7.93	72.16	13.43	22.06	4.92	74.91	56.86	23.73	7.00
Number of sub-product transformations		1.08	0.28	1.01	0.08	1.01	0.09	1.08	0.27	1.35	0.48	1.23	0.43

Note: The official exchange rate in the year of the survey are 0.04492 USD/ Birr; 0.1305 USD/ Quetzal; 0.0411 USD/ Lempiras; 0.297 USD/ Soles (www.oanda.com)

Results

As shown in Table 5, we estimate loss levels at the producer, middlemen, and processor levels separately, and alternatively apply the four estimation methodologies. We use the loss figures estimated with the attribute method (A-measure) as our dependent variable and add up losses at each level to obtain loss figures for the entire value chain[13]. Some observations are lost due to missing values and outliers[14]. Loss figures include both the quantitative loss, i.e. the product entirely disappeared from the value chain, and the qualitative loss, i.e. the product affected by quality deteriorations. Losses are alternatively expressed in weight and values, with the latter providing information regarding the economic damage caused by the loss. Appendix A presents a detailed decomposition of all the methods by commodity and country.

Loss figures across all value chains fluctuate between 6 and 25 percent of total production and of the total produced value. Loss figures are consistently largest at the producer level and smallest at the middleman level. Across the different estimation methodologies, loss at the producer level represents between 60 and 80 percent of the total value chain loss, while the average loss at the middleman and processor levels lies around 7 and 19 percent, respectively. It is important to mentioned that these losses don't include the yield gaps which could vary between 50-80%. These yield gaps represent the distance to the production possibility frontier is defined as the distance of the sale quantities or prices and the frontier (see Delgado et.al 2017 for further details).

Differences across methodologies are salient, especially at the producer level. While the estimation results from the C-, A-, and P-methods are close and differences are mostly not statistically significant, the aggregate self-reported method reports systematically lower loss figures. As shown in Table 1, these gaps are largest in the beans value chain in Honduras and potato value chain in Peru, where self-reported loss estimates are between 10 and 15 percentage points lower than those estimated with any of the other methods. Differences across methods are smallest in the Ethiopian teff value chain, but estimates from the C-, A-, and P-methods remain significantly larger than those estimated with the S-method.

Percentage losses expressed in value tend to be slightly smaller than those expressed in weight for the S-method; however, this difference is found particularly in the A-method, indicating that some quality degradations at the farm-level do not seem to be punished by the market. The category-method leads to results which are more similar in terms of weight and value loss.

Tables A2 – A8 in the Appendix split loss figures at the producer level into quantities left in the field, (i.e. good quality product which is not harvested), quantities affected by quality deterioration previous to harvest, and quantities totally lost or affected by quality deteriorations during post-harvest activities on the farm. The latter can include cleaning, winnowing, threshing, drying, storage, transport activities, etc., depending on the value chain and country. The quantities left in the field are fairly small, at around 1 percent of total production, or are even neglectable in the case of teff. The percentage value of the unharvested product in terms of the total produced value is even smaller, indicating that the product left in the field tends to be of lower quality than the harvested product. Overall, the quantity affected by loss at pre-harvest is considerably larger than the quantities totally

[13] For the middlemen and processors, we assume that the percentage lost on their purchase in the month prior to the survey corresponds to the average middleman and processor loss in the value chain
[14] We use a ''winsorizing" technique, replacing extreme outliers beyond the 99th percentile with missing values under the assumption that all extreme values are due to measurement error

lost or affected by a loss during post-harvest activities. This indicates that the largest losses occur in the field or during harvest activities.

With the exception of the bean value chain in Honduras, loss figures across methodologies are similar and not statistically different for middlemen. At the wholesale level, losses fluctuate between 2 and 3 percent.

Causes behind the loss

Figure 3 (a-g) presents the major reasons reported by farmers as the explanation for their pre-harvest loss, their crop left in the field, and their post-harvest loss. In the specific case of pre-harvest loss, the major reasons reported by farmers included pests and diseases and lack of rainfall; teff was the exception, with lack of rainfall being the major reported reason for pre-harvest loss. When looking at the produce left in the field, the major reason for the loss is a lack of appropriate harvesting techniques. Finally, the loss reported at the post-harvest level is due mostly to damage done during selection, as a result of workers' lack of training and experience in selecting the produce.

Tables 6-9 try to control for the heterogeneity among farmer characteristics through regression analysis. The result show that education and experience tend to be correlated with a reduction in losses. In particular, results on education are significant for the potato value chain in Ecuador and Peru and the maize value chain in Honduras. The number of years in which a producer has been involved in the production of a specific crop significantly correlates with a reduction in losses in the potato value chain in Ecuador and Peru, the maize value chain in Guatemala, and the teff value chain in Ethiopia. While we only have farmers' income data for Peru and Ecuador, we find that when a producer's main income stems from an agricultural activity it is correlated with a statistically significant lower loss; this result is in line with the effects we find for crop cultivation experience.

The large majority of farmers are men, but there is no clear gender pattern in food loss across countries. For example, being a male farmer tends to be correlated with a decrease in beans loss, but it increases maize loss in Guatemala. No gender effect is detected in the other commodity chains.

Costs to reach markets significantly correlated with increases in losses in Peru, Guatemala, and Ethiopia, indicating that the absence of markets can represent important limitations for farmers. This is directly linked to previous work which shows the importance of access to better roads to reduce food loss across the value chain (see for example Rosegrant et.al 2015).

Technology and improved seeds also matter. The more resistant pests and weather 'unica' potato variety reduce loss in Ecuador compared to the 'capiro' and 'supercholavarieties. Similarly, the use of improved seeds is correlated with a decrease in losses in the maize and bean value chains in Honduras. In potato value chains, the harvesting tool used considerably impacts loss; traditional hoes break the potato during the harvest. In Peru, new (mechanized) tools are used to reduce this damage. Both the tractor and the 'lampa' are correlated with a significant reduction of the share of potato that is lost during harvest. The potato value chain in Ecuador, on the other hand, is more traditional, with very few mechanical tools used. In Ecuador, no alternative tools to the hoe were mentioned by the surveyed farmers. In Ecuador, an increased number of activities to 'take care of the crop' (such as irrigation and plant trimming) and a larger labor force are shown to reduce the likelihood of loss in this more traditional potato value chain.

In the maize, bean, and teff value chains under analysis, production activities are shown to have little impact on food loss. The exception is the bean value chain in Guatemala, where mechanical production activities are shown to be positively correlated with an increase loss; mechanical harvesting techniques likely damage the crop and/or leave crops in the field (especially if the machines are of poor quality).

When analyzing how the type and number of post-harvest activities carried out by the farmers affect loss, we found that both the overall number of post-harvest activities and the increased mechanization in some commodity chains can have opposite effects. The total number of post-harvest activities, including activities such as winnowing, threshing, drying, putting in bags, transporting, etc., decrease loss in the Guatemalan bean value chain but increases loss in the Guatemalan maize value chain and the Ethiopian teff value chain. In both latter cases, the increased loss mainly originates from post-harvest winnowing and packaging activities.

Mechanical post-harvest activities are not very widespread, with mechanical drying, winnowing, and threshing activities only being observed in the maize and bean value chains in Honduras and Guatemala. Post-harvest mechanization has no effect in the maize value chains in either Honduras or Guatemala. In the bean value chain, on the other hand, increased mechanization in the drying and winnowing activities reduces loss in Guatemala, but mechanical threshing increases loss in Honduras. Farmers likely incur grain damage, cracks and lesions when mechanically (instead of manually) stripping the grain from the plant; this makes the grain more vulnerable to insects, as well as less visually appealing. Only a very few farmers (6 percent of our sample) engage in mechanical threshing in Honduras (and no producers do so in Guatemala). Mechanical transport with a car significantly increases loss in Guatemala and Ecuador, pointing to important losses during transport, especially if larger distances are traveled.

Potato farmers in Peru and Ecuador rarely store their product, but the opposite is true for the other commodity chains. Storage significantly increases loss in the bean value chains in Honduras and Guatemala, as well as in the maize value chain in Honduras. For beans in Honduras, storage duration is significantly correlated with increases in losses. These storage losses are shown to be mitigated by improved storage techniques (silos) in both Honduras and Guatemala or the use of 'pits' rather than other traditional storage facilities in Ethiopia (no modern storage techniques are used for teff in Ethiopia). Storage conservation activities, such as chemical or natural fumigation and/ or increased ventilation, are correlated with a decrease of storage losses in Honduras.

Finally, unfavorable climatic conditions and pest and diseases are mentioned most often as problems faced by farmers during production. Farmers most often mentioned limited knowledge and access to equipment, credit, and markets as a challenge to increased production of higher quality products. All of these factors are also shown to affect food losses.

Conclusions

Improving the methodology used to measure food loss across food value chains, as well as identifying the causes and costs of loss across value chains, is critical to promoting food loss reduction interventions and setting priorities for action.

We address the existing measurement gap by developing and testing three new methodologies that aim to reduce measurement error and that allow us to assess the magnitude of food loss. The methods account for loss from pre-harvest to product distribution and include both quantity loss and quality deterioration. We apply the instrument to producers, middlemen, and processors in seven staple food value chains in five developing countries. Comparative results suggest that losses are highest at the producer level and that most product deterioration occurs prior to harvest. Self-reported measures, which have been frequently used in the literature, seem to consistently underestimate food loss. Loss figures across all value chains fluctuate between 6 and 25 percent of total production and of the total produced value. Loss figures are consistently largest at the producer level and smallest at the middleman level. Across the different estimation methodologies, losses at the producer level represent between 60 and 80 percent of the total value chain losses, while the average loss at the middleman and processor levels lies around 7 and 19 percent, respectively.

Differences across methodologies are salient, especially at the producer level. While the estimation results from the three new methods we implement are close and the differences are mostly not statistically significant, the aggregate self-reported method reports systematically lower loss figures. In addition, our figures are larger than those recently obtained by Kaminski and Christiansen (2014) and Minten et al. (2016). These differences are due to the inclusion of qualitative loss (not previously considered) and to the fact that we also include quality and quantity effects.

Addressing food loss across the value chain first requires a common understanding of the concept by all actors,[15] as well as a collaborative effort to collect better micro-data across different commodities and contexts. The presence of pests, lack of rainfall, and lack of appropriate post-harvest technologies seem to be the major factors behind the losses identified in our study. A lack of appropriate storage facilities (FAO, 2011; Liu, 2014) and efficient transport systems (Rolle, 2006) are also considered to be important micro-causes of food loss; however, other causes, ranging from crop variety choices, pre-harvest pests, and processing and retail decisions, are also important. Micro-causes can be linked to broader meso-causes, overarching different stages of the value chain; for example, the HLPE report (2013) sees credit constraints as one of the main bottlenecks to the successful adoption of technologies to reduce food loss and waste. Like Kaminski and Christiaensen (2014), we also identify a lack of education as an important bottleneck.

Finally, policymakers and value chain actors need to translate these insights into action. International organizations have the power to bring the important topic of food loss to the table and create platforms for information exchange; at the same time, individual states play a key role in creating a successful enabling environment. All public and private value chain actors need to work together to transform theory into concrete PWLF reduction interventions.

[15] A good step in this direction has been made by the multi-stakeholder “Food Loss and Waste Standard and Protocol” initiative, although this initiative does exclude pre-harvest loss from its definition.

Figure 3: Self-Reported Causes of of Pre-Harvest Losses

Figure 3.a: Potato Ecuador

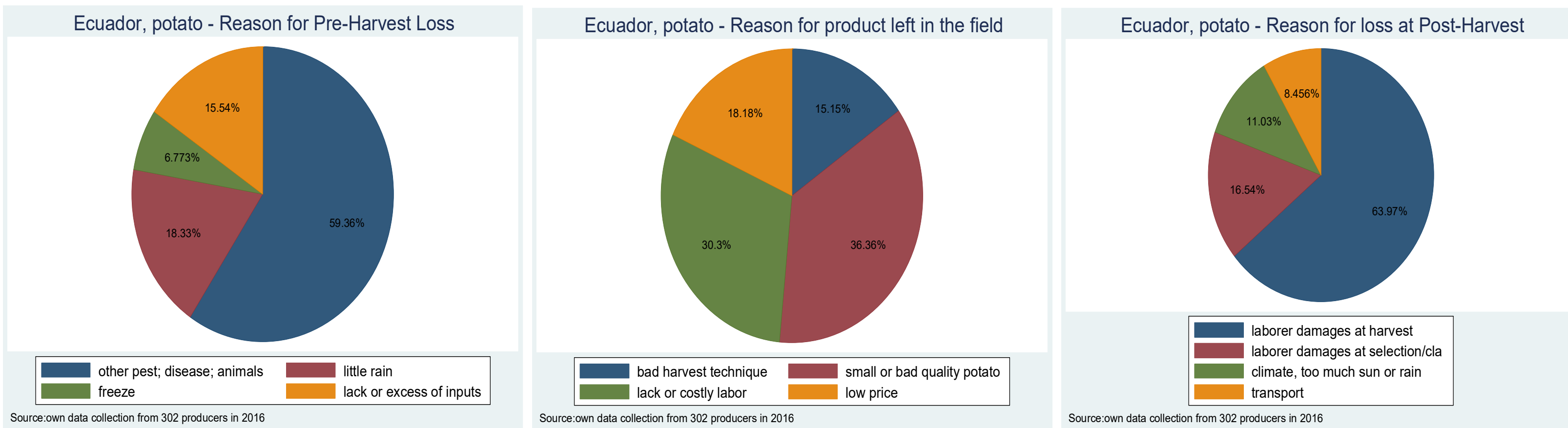


Figure 3.b: Potato Peru

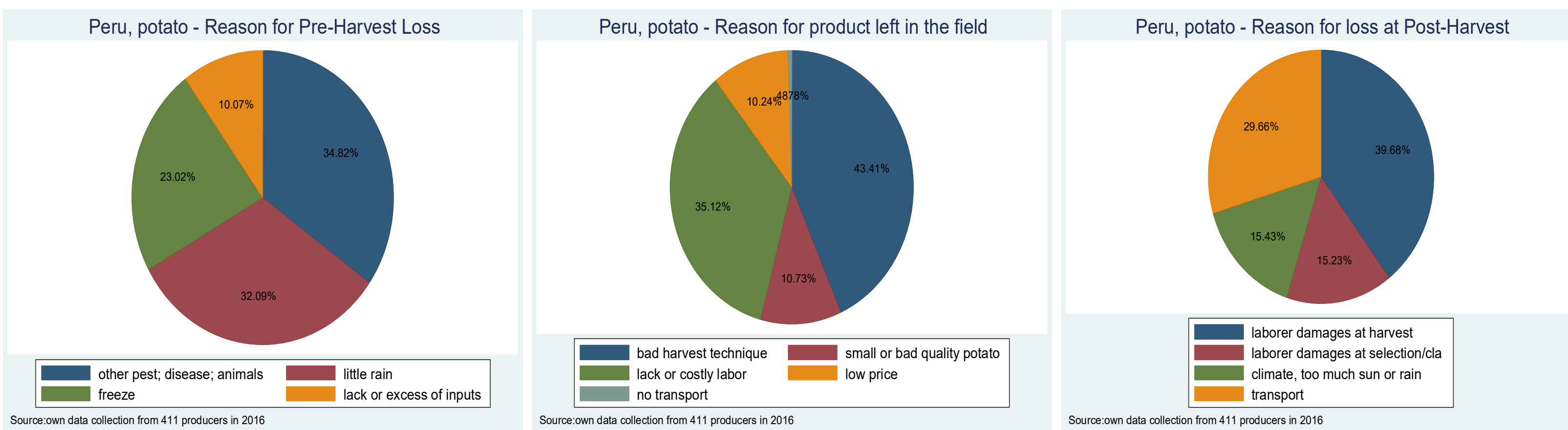


Figure 3.c: Beans Guatemala

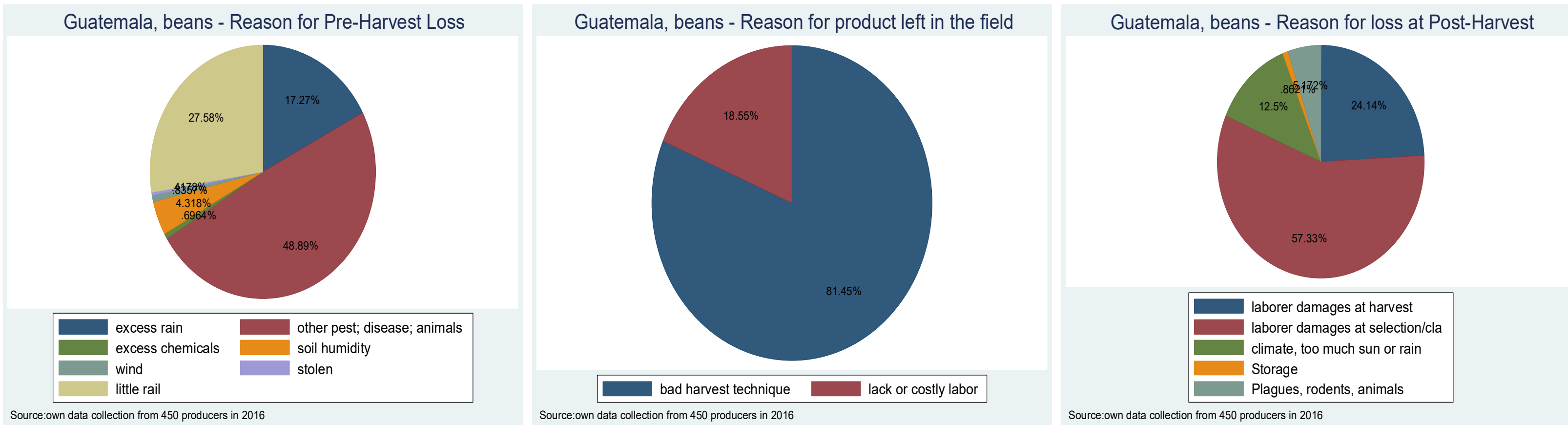


Figure 3.d: Beans Honduras

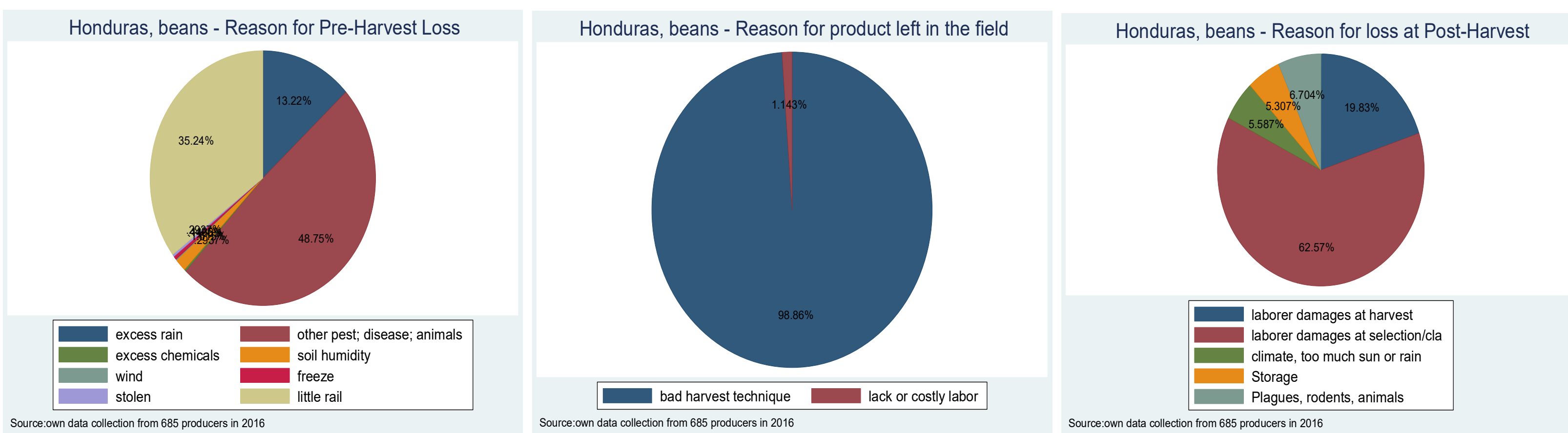


Figure 3.e: Maize Guatemala

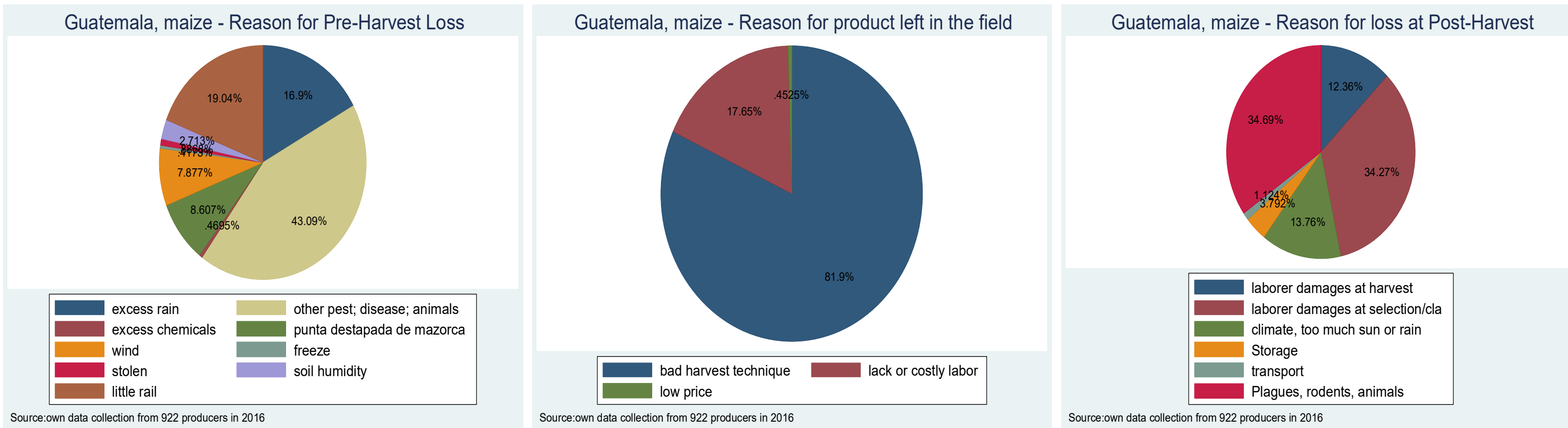


Figure 3.f: Maize Honduras

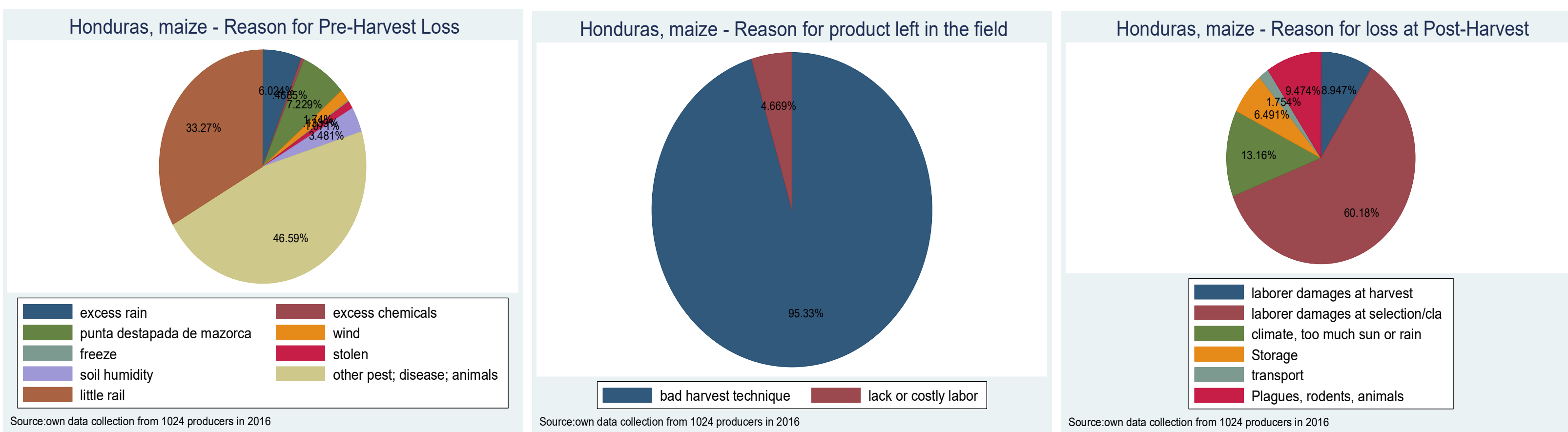
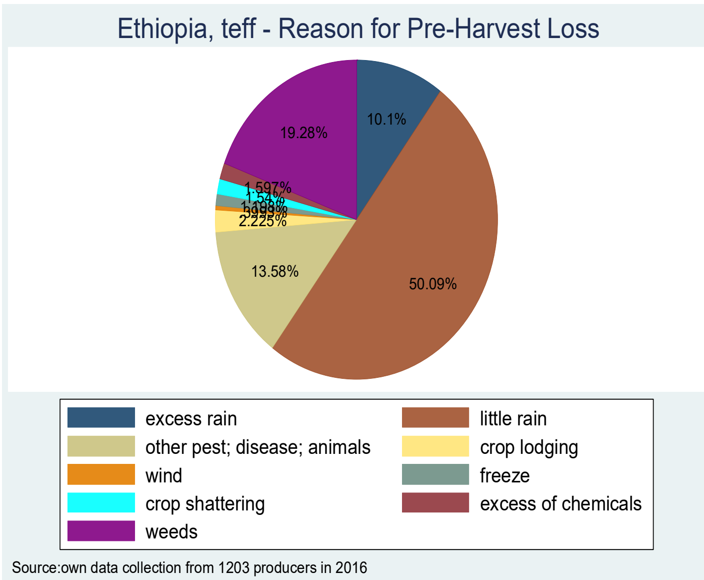


Figure 3.g: Teff Ethiopia



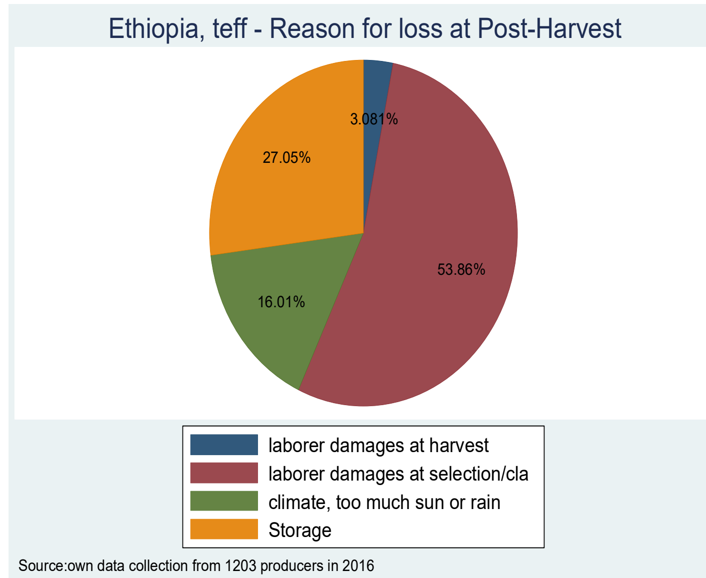


Table 5: Quantitative and qualitative food losses along the value chain, estimated with four methodologies

		Ecuador: potato				Peru: potato				Guatemala : beans				Guatemala : maize				Honduras : beans				Honduras : maize				Ethiopia: teff			
		S	C	A	P	S	C	A	P	S	C	A	P	S	C	A	P	S	C	A	P	S	C	A	P	S	C	A	P
Producer	*Nb of observations*	*286*				*355*				*431*				*884*				*650*				*988*				*1,186*			
	Kg lost	1,498	5,926	4,982	4,146	3,548	9,216	11,523	7,998	7.47	16.01	24.79	26.59	55.67	137.74	194.93	178.73	26.47	66.96	114.16	129.69	78.61	186.08	198.19	284.26	27.35	57.02	281.41	47.59
	% of total production that is lost	**8.11%**	**12.82%**	**12.17%**	**11.84%**	**9.38%**	**15.99%**	**19.62%**	**19.84%**	**9.77%**	**12.80%**	**19.67%**	**16.72%**	**9.84%**	**14.58%**	**20.46%**	**14.10%**	**6.25%**	**13.27%**	**19.77%**	**17.39%**	**9.95%**	**16.69%**	**15.95%**	**17.41%**	**6.86%**	**8.67%**	**19.76%**	**8.69%**
	Value lost (USD)	269	1,543	1,007	990	454	2,116	2,202	1,805	8	26	33	38	18.37	58.07	54.72	75.93	19	74	90	117	23.30	65.43	65.19	99.12	40.24	97.98	91.03	73.91
	% of value of total production that is lost	**6.22%**	**13.78%**	**10.03%**	**11.84%**	**5.58%**	**16.73%**	**16.13%**	**19.84%**	**7.72%**	**12.95%**	**17.97%**	**16.72%**	**7.72%**	**14.76%**	**13.45%**	**14.10%**	**5.23%**	**15.34%**	**17.56%**	**17.39%**	**8.87%**	**16.64%**	**15.41%**	**17.41%**	**6.26%**	**9.49%**	**9.02%**	**8.69%**
Middlemen	*Nb of observations*	*176*				*81*				*162*				*151*				*225*				*121*							
	Kg lost	20.96	11.90	63.65	26.89	2.05	1.39	5.78	5.57	0.05	0.06	0.05	0.05	0.20	0.19	0.15	0.14	0.28	0.19	0.43	0.42	0.31	0.42	0.53	0.46				
	% of total purchase that is lost	**1.70%**	**0.91%**	**1.77%**	**1.52%**	**1.22%**	**1.60%**	**3.72%**	**2.05%**	**0.63%**	**0.66%**	**0.58%**	**0.57%**	**0.63%**	**0.66%**	**0.58%**	**0.57%**	**0.74%**	**0.55%**	**0.93%**	**1.57%**	**0.60%**	**0.59%**	**0.29%**	**0.65%**	-			
	Value lost (USD)	232	284	685	518	515	490	1,261	2,694	4.11	3.75	3.80	3.24	3.88	3.30	2.34	2.47	9.51	14.06	21.85	22.68	7.78	5.77	8.99	8.83				
	% of value of total purchase that is lost	**1.36%**	**1.65%**	**1.55%**	**1.91%**	**1.34%**	**1.49%**	**2.89%**	**2.83%**	**0.78%**	**0.67%**	**0.67%**	**0.62%**	**0.78%**	**0.67%**	**0.67%**	**0.62%**	**0.45%**	**1.08%**	**1.58%**	**1.83%**	**0.63%**	**0.41%**	**0.31%**	**0.72%**				
Wholesaler	*Nb of observations*	*146*				*152*				*120*				*104*				*121*				*118*							
	Kg lost	0.83	0.83^	0.83^	0.83^	0.06	0.06^	0.06^	0.06^	0.05	0.05^	0.05^	0.05^	0.54	0.54^	0.54^	0.54^	0.05	0.05^	0.05^	0.05^	0.47	0.47^	0.47^	0.47^				
	% of total purchase that is lost	**2.45%**	**2.45%^**	**2.45%^**	**2.45%^**	**2.27%**	**2.27%^**	**2.27%^**	**2.27%^**	**2.94%**	**2.94%^**	**2.94%^**	**2.94%^**	**2.94%**	**2.94%^**	**2.94%^**	**2.94%^**	**3.67%**	**3.67%^**	**3.67%^**	**3.67%^**	**3.97%**	**3.97%^**	**3.97%^**	**3.97%^**	-			
	Value lost (USD)	15	14.59^	14.59^	14.59^	41.06	41.06^	41.06^	41.06^	3.73	3.73^	3.73^	3.73^	0.52	0.52^	0.52^	0.52^	1.18	1.18^	1.18^	1.18^	7.62	7.62^	7.62^	7.62^				
	% of value of total purchase that is lost	**2.27%**	**2.27%^**	**2.27%^**	**2.27%^**	**3.31%**	**3.31%^**	**3.31%^**	**3.31%^**	**3.42%**	**3.42%^**	**3.42%^**	**3.42%^**	**3.42%**	**3.42%^**	**3.42%^**	**3.42%^**	**1.96%**	**1.96%^**	**1.96%^**	**1.96%^**	**3.92%**	**3.92%^**	**3.92%^**	**3.92%^**				
Entire value chain	% of total production that is lost	**11.50%**	**16.18%**	**16.39%**	**15.80%**	**12.87%**	**19.86%**	**25.62%**	**24.17%**	**13.34%**	**16.40%**	**23.19%**	**20.23%**	**13.41%**	**18.18%**	**23.98%**	**17.61%**	**8.95%**	**17.49%**	**24.37%**	**22.63%**	**14.52%**	**21.25%**	**20.21%**	**22.03%**	**6.86%**	**8.67%**	**19.76%**	**8.69%**
	% of value of total production that is lost	**9.86%**	**17.71%**	**13.85%**	**16.02%**	**10.23%**	**21.53%**	**22.32%**	**25.97%**	**11.93%**	**17.05%**	**22.06%**	**20.76%**	**11.93%**	**18.85%**	**17.55%**	**18.14%**	**7.65%**	**18.39%**	**21.11%**	**21.18%**	**13.42%**	**20.98%**	**19.64%**	**22.06%**	**6.26%**	**9.49%**	**9.02%**	**8.69%**

Note: S= Self-reported method, C= Category method; A= Attribute method; P= Price method; ^ Data are imputed from the 'Self-reported method'

Quantitative Loss == Total loss (product disappeared); Qualitative Loss= Product affected by quality deteriorations (product did not entirely disappear but quality is reduced)

The official exchange rate in the year of the survey are 0.04492 USD/ Birr; 0.1305 USD/ Quetzal; 0.0411 USD/ Lempiras; 0.297 USD/ Soles (www.oanda.com)

Table 6: Determinants of losses in the potato value chains in Ecuador and Peru (GLM model);
Dependent variable: share of product lost at pre-harvest and post-harvest (A- measure)

		ECUADOR			PERU		
Socio-economic variables	Male producer	0.000	0.002	0.002	0.005	0.011	0.012
		(0.039)	(0.026)	(0.023)	(0.033)	(0.023)	(0.025)
	Age of producer (in 10 years)	0.021*	0.020	0.019	0.002	0.004	-0.001
		(0.012)	(0.014)	(0.014)	(0.025)	(0.026)	(0.027)
	Education: Primary (vs no Education)	-0.102**	-0.076*	-0.068*	-0.032***	-0.007	-0.018
		(0.044)	(0.045)	(0.042)	(0.007)	(0.017)	(0.016)
	Education: Secondary or higher (vs no Edu)	-0.057	-0.031	-0.022	-0.061	-0.011	-0.03
		(0.037)	(0.035)	(0.046)	(0.077)	(0.057)	(0.045)
	Experience in cultivation of potato (in 10 years)	-0.088***	-0.115***	-0.102***	-0.015	-0.01	-0.006
		(0.013)	(0.036)	(0.030)	(0.034)	(0.032)	(0.030)
	Main income from agriculture (vs non-agric)	-0.015***	-0.007*	-0.009**	-0.089**	-0.048	-0.049
		(0.005)	(0.004)	(0.004)	(0.042)	(0.035)	(0.037)
Market	Cost to reach market (USD/ Kg)	-0.004	-0.006	-0.007	1.448**	1.150**	0.983
		(0.005)	(0.005)	(0.005)	(0.568)	(0.537)	(0.628)
Production	log(Total production potato)		-0.009	-0.008		-0.021	-0.022*
			(0.006)	0.006		(0.013)	(0.012)
	Improved seeds (dummy)		0.037	0.031		0.008	0.000
			(0.065)	0.07		(0.030)	(0.025)
	Resistant potato variety		-0.039**	-0.038**		-0.001	0.004
			(0.018)	0.017		(0.041)	(0.039)
	Number of different inputs applied[a]		0.007	-0.005		-0.03	-0.01
			(0.032)	0.026		(0.070)	(0.080)
	Number of different field maintenance activities[b]		-0.010**	-0.010*		0.003	0.003
			(0.005)	0.006		(0.013)	(0.014)
	Number of production activities done mechanically[c]		0.014	0.017		-0.029*	-0.026**
			(0.045)	0.038		(0.016)	(0.012)
	Harvest technique: tractor vs azadon					-0.165***	-0.166***
						(0.017)	(0.018)
	Harvest technique: lampa vs azadon					-0.177***	-0.173***
						(0.014)	(0.017)
	Hired labor for harvest		-0.071***	-0.072***		-0.037	-0.012
			(0.007)	(0.009)		(0.026)	(0.032)
Post-harvest	Storage dummy		0.019	0.013		-0.002	-0.003
			(0.015)	(0.015)		(0.034)	(0.037)
	Nb of post-harvest activities[d]		-0.046	-0.045		-0.002	-0.01
			(0.063)	(0.050)		(0.003)	(0.007)
	Mechanical transport (not sold on plot)		0.017**	0.023**		0.011	0.025
			(0.007)	0.012		(0.042)	(0.022)
Production problems & limitations to produce high quality (as perceived by the producer)	Climate			0.033**			(0.020)
				(0.016)			(0.026)
	Pests			-0.005			0.063**
				(0.015)			(0.029)
	Limited knowledge			0.032***			-0.019
				(0.007)			(0.026)
	Limited equipment			-0.012			0.118***
				(0.013)			(0.036)
	Limited market access			0.035			-0.011
				(0.042)			(0.040)
	Limited credit access			-0.019			0.055*
				(0.025)			(0.032)
Location fixed effects		parroquia	parroquia	parroquia	district	district	district
Agroecological zone dummies		yes	yes	yes	yes	yes	yes
No. of Obs.		287	287	287	369	369	369

Note: Marginal effects from GLM models are reported. Standard errors in parenthesis clustered at the province level for Peru and at the canton level for Ecuador. [a] This includes fertilizers, insecticides, herbicides and fungicides; [b] This includes irrigation, 'aporque' and corte del yuyo; [c] Machine driven, instead of manual, activities include: soil preparation, sowing, pest control, fertilizer application, weeding, 'aporque', 'corte del yuyo', harvest; [d] This refers to selection, classification, drying, and transport after drying

Table 7: Determinants of losses in the bean value chains in Guatemala and Honduras (GLM model);
Dependent variable: share of product lost at pre-harvest and post-harvest (A- measure)

		Honduras				Guatemala			
Socio-economic variables	Male producer	-0.056	-0.061	-0.067	-0.101*	-0.063***	-0.069***	-0.055***	-0.065***
		(0.045)	(0.053)	(0.046)	(0.054)	(0.023)	(0.021)	(0.021)	(0.023)
	Age of producer (in 10 years)	-0.002	-0.002	-0.001	-0.003	0.001	0.001	0.001*	0.001
		(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
	Education: Primary (vs no education)	-0.033	-0.035	-0.019	-0.033	0.007	0.006	0.009	0.003
		(0.029)	(0.033)	(0.037)	(0.025)	(0.033)	(0.036)	(0.031)	(0.034)
	Education: Secondary or higher (vs no education)	-0.124*	-0.107*	-0.090*	-0.155**	0.069	0.072	0.068	0.065
		(0.064)	(0.065)	(0.058)	(0.076)	(0.068)	(0.065)	(0.059)	(0.067)
	Experience in cultivation of beans (in 10 years)	0.008	0.011	0.013	0.016	-0.005	-0.003	-0.005	-0.003
		(0.009)	(0.009)	(0.010)	(0.012)	(0.007)	(0.007)	(0.007)	(0.007)
Market	Cost to reach market (USD/ Kg)	-1.802	-2.045	-2.189	-1.164	0.023**	0.023**	0.019*	0.024*
		(1.341)	(1.511)	(1.494)	(1.591)	(0.011)	(0.012)	(0.012)	(0.012)
Production	log(Total production beans)		-0.020**	-0.020**	-0.021*		0.002	0.005	0.012
			(0.010)	(0.009)	(0.011)		(0.015)	(0.016)	(0.011)
	Time of planting: primera vs postrera		-0.02	-0.009	-0.042***		0.037	0.04	0.041
			(0.029)	(0.028)	(0.015)		(0.031)	(0.033)	(0.029)
	Improved seeds (dummy)		-0.043**	-0.058***	-0.021		-0.066	-0.07	-0.056
			(0.020)	(0.020)	(0.021)		(0.044)	(0.051)	(0.057)
	Number of different inputs applied[a]		0.002	-0.001	0.009		0.01	0.007	0.005
			(0.005)	(0.005)	(0.006)		(0.010)	(0.007)	0.009
	Number of different production activities[b]		0.043	0.049	0.02		0	0.001	0.042
			(0.044)	(0.040)	(0.059)		(0.016)	(0.012)	0.029
	Number of production activities done mechanically[c]		0.003	0.005	0.005		-0.001	-0.012	0
			(0.017)	(0.019)	(0.018)		(0.013)	(0.011)	0.012
	Hired labor for harvest		-0.01	-0.029	0.007		-0.001	-0.004	0.004
			(0.047)	(0.049)	(0.043)		(0.012)	(0.012)	(0.013)
Post-harvest	Storage dummy		0.095***	0.076***			0.125*	0.125***	
			(0.033)	(0.028)			(0.065)	(0.045)	
	Nb of post-harvest activities[d]		0.019	0.018	0.029		-0.027**	-0.027**	-0.028**
			(0.024)	(0.020)	(0.018)		(0.012)	(0.012)	(0.014)
	Mechanical drying and winnowing		0.018	0.020	-0.006		-0.242***	-0.207***	-0.238***
			(0.055)	(0.050)	(0.027)		(0.076)	(0.077)	(0.081)
	Mechanical threshing activity		0.105**	0.109***	0.101***				
			(0.041)	(0.032)	(0.034)				
	Mechanical transport		-0.010	0.000	0.001		0.057**	0.052*	0.070**
			(0.040)	(0.033)	(0.034)		(0.029)	(0.031)	(0.030)
Storage	Storage time (in months)				0.012***				-0.004
					(0.004)				(0.003)
	Storage: Silo vs Traditional storage in 'troja'				-0.046*				-0.005
					(0.025)				(0.023)
	Storage: Silo vs Traditional storage in house				-0.004				-0.128***
					(0.026)				(0.029)
	Number of storage conservation activities[e]				-0.036*				-0.01
					(0.020)				(0.012)
Production problems & limitations to produce high quality (as perceived by the producer)	Climate			0.057***				0.034	
				(0.020)				(0.024)	
	Animals/ rodents			-0.005				0.050***	
				(0.023)				(0.015)	
	Pests			0.035				0.031	
				(0.024)				(0.024)	
	Diseases			0.028				0.053**	
				(0.018)				(0.024)	
	Limited market access			0.125***				0.015	
				(0.041)				(0.029)	
Location fixed effects		municipality	municipality	municipality	municipality	municipality	municipality	municipality	municipality
Agroecological zone dummies		yes	yes	yes	yes	yes	yes	yes	yes
No. of Obs.		650	644	644	574	431	431	431	426

Note: Marginal effects from GLM models are reported. Standard errors in parenthesis clustered at the department level for Honduras and Guatemala. [a] This includes fertilizers, insecticides, herbicides and fungicides; [b] This includes irrigation and 'chapeo'; [c] Machine driven, instead of manual, production activities include: cleaning, sowing, herbicide application, pest control, fertilizer application, and harvest; [d] This refers to winnowing (sopla), threshing (desgrane), drying, putting in bags, and transport; e This includes chemical fumigation, natural fumigation, and ventilation

Table 8: Determinants of losses in the maize value chains in Guatemala and Honduras (GLM model);
Dependent variable: share of product lost at pre-harvest and post-harvest (A- measure)

		Honduras				Guatemala			
Socio-economic variables	Male producer	-0.008	-0.011	-0.014	-0.028	0.040*	0.041*	0.041	0.044*
		(0.027)	(0.028)	(0.025)	(0.034)	(0.022)	(0.026)	(0.026)	(0.026)
	Age of producer (in 10 years)	-0.002	-0.002*	-0.001*	-0.002	0.001	0.001	0.001	0.000
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
	Education: Primary (vs no education)	0.007	0.012	0.007	0.006	-0.013	-0.028	-0.023	-0.034
		(0.018)	(0.018)	(0.017)	(0.018)	(0.029)	(0.028)	(0.027)	(0.028)
	Education: Secondary or higher (vs no education)	0.002	0.005	-0.003	0.006	0.001	-0.009	0	-0.017
		(0.055)	(0.058)	(0.058)	(0.057)	(0.038)	(0.032)	(0.029)	(0.039)
	Experience in cultivation of maize (in 10 years)	0.011	0.01	0.009	0.01	-0.011**	-0.006	-0.010*	-0.004
		(0.011)	(0.010)	(0.010)	(0.010)	(0.005)	(0.006)	(0.006)	(0.006)
Market	Cost to reach market (USD/ Kg)	-0.019	-0.261	-0.198	-0.042	0.037***	0.037***	0.037***	0.035***
		(0.723)	(0.712)	(0.801)	(0.765)	(0.011)	(0.011)	(0.012)	(0.011)
Production	log(Total production maize)		0.006	0.009	0.013		-0.011	-0.01	-0.006
			(0.009)	(0.008)	(0.011)		(0.013)	(0.011)	(0.014)
	Time of planting: primera vs postrera		0.015	0.028	0.022		-0.048	-0.062	-0.047
			(0.018)	(0.017)	(0.021)		(0.050)	(0.047)	(0.051)
	Improved seeds (dummy)		-0.044***	-0.038***	-0.036***		-0.005	-0.013	-0.002
			(0.011)	(0.012)	(0.012)		(0.014)	(0.015)	(0.013)
	Number of different inputs applied[a]		0.004	-0.004	0.009		-0.002	-0.011	-0.005
			(0.010)	(0.010)	0.011		(0.010)	(0.007)	0.009
	Number of different production activities[b]		-0.003	-0.008	-0.001		0.007	0.011	0.005
			(0.022)	(0.021)	0.023		(0.029)	(0.048)	0.028
	Number of production activities done mechanically[c]		0.012	0.012	0.006		0.032***	0.034***	0.035***
			(0.008)	(0.008)	0.015		(0.012)	(0.010)	0.011
	Hired labor for harvest		0.033	0.019	0.043		0.009	0.011	0.009
			(0.031)	(0.034)	(0.026)		(0.012)	(0.013)	(0.012)
Post-harvest	Storage dummy		0.059**	0.054***			-0.045	-0.039	
			(0.025)	(0.019)			(0.030)	(0.034)	
	Nb of post-harvest activities[d]		0.009	0.004	0.008		0.018**	0.015*	0.020**
			(0.008)	(0.008)	(0.009)		(0.009)	(0.009)	(0.008)
	Mechanical drying and winnowing		-0.038	-0.031	-0.034		0.001	0.021	-0.007
			(0.025)	(0.021)	(0.024)		(0.009)	(0.014)	(0.010)
	Mechanical threshing activity		-0.015	-0.023	-0.010		-0.036	-0.042	-0.049
			(0.034)	(0.031)	(0.031)		(0.042)	(0.046)	(0.040)
	Mechanical transport		-0.017	-0.014	-0.022		0.059***	0.061***	0.054***
			(0.020)	(0.020)	(0.021)		(0.016)	(0.014)	(0.015)
Storage	Storage time (in months)				-0.003				-0.004
					(0.003)				(0.003)
	Storage: Silo vs Traditional storage in 'troja'				-0.096*				-0.165***
					(0.056)				(0.064)
	Storage: Silo vs Traditional storage in house				-0.02				-0.100
					(0.014)				(0.066)
	Number of storage conservation activities[e]				-0.018*				0.005
					(0.011)				(0.011)
Production problems & limitations to produce high quality (as perceived by the producer)	Climate			0.01				0.072***	
				(0.021)				(0.018)	
	Animals/ rodents			0.035**				-0.009	
				(0.017)				(0.015)	
	Pest (plaga)			0.041***				0.005	
				(0.011)				(0.014)	
	Disease			0.032**				0.057***	
				(0.014)				(0.016)	
	Limited market access			0.013				0.011	
				(0.024)				(0.025)	
Location fixed effects		municipality	municipality	municipality	municipality	municipality	municipality	municipality	municipality
Agroecological zone dummies		yes	yes	yes	yes	yes	yes	yes	yes
No. of Obs.		988	972	972	891	876	876	876	852

Note: Marginal effects from GLM models are reported. Standard errors in parenthesis clustered at the department level for Honduras and Guatemala. [a] This includes fertilizers, insecticides, herbicides and fungicides; [b] This includes irrigation and 'chapeo'; [c] Machine driven, instead of manual, production activities include: cleaning, sowing, herbicide application, pest control, fertilizer application, and harvest; [d] This refers to winnowing (sopla), threshing (desgrane), drying, putting in bags, and transport; [e] This includes chemical fumigation, natural fumigation, and ventilation

Table 9: Determinants of losses in the teff value chain in Ethiopia (GLM model);
Dependent variable: share of product lost at pre-harvest and post-harvest (A- measure)

		Ethiopia			
Socio-economic variables	Male producer	0.015	0.015	0.026	0.004
		(0.039)	(0.039)	(0.028)	(0.039)
	Age of producer (in 10 years)	0.001	0.001*	0.001	0.001
		(0.001)	(0.001)	(0.001)	(0.001)
	Education: Primary (vs no education)	0.008	0.01	0.016	0.01
		(0.016)	(0.015)	(0.010)	(0.018)
	Education: Secondary or higher (vs no education)	-0.013	-0.011	-0.006	-0.013
		(0.019)	(0.015)	(0.015)	(0.017)
	Experience in cultivation of teff (in 10 years)	-0.022**	-0.023**	-0.025**	-0.018*
		(0.009)	(0.010)	(0.011)	(0.010)
Market	Time to reach market (in 10 hours)	0.538*	0.557*	0.537**	0.527*
		(0.282)	(0.301)	(0.268)	(0.303)
Production	log(Total production teff)		-0.008	-0.012	-0.001
			(0.012)	(0.012)	(0.011)
	Improved seeds (dummy)		-0.020	-0.012	-0.012
			(0.024)	(0.025)	(0.025)
	Main variety: hybrid Quncho		-0.041	-0.030	-0.040
			(0.033)	(0.032)	(0.035)
	Number of different inputs applied[a]		0.030	0.040**	0.026
			(0.018)	(0.018)	(0.019)
	Number of production activities done mechanically[b]		0.007	-0.054	-0.004
			(0.037)	(0.037)	(0.049)
	Hired labor for harvest		-0.018	-0.004	-0.024
			(0.025)	(0.022)	(0.023)
Post-harvest	Storage dummy		-0.001	-0.018	
			(0.052)	(0.034)	
	Nb of post-harvest activities[c]		0.065***	0.049**	0.072***
			(0.019)	(0.019)	(0.023)
Storage	Storage time (in months)				0.003
					(0.004)
	Storage: Granary (dung or basket) vs bag				0.012
					(0.044)
	Storage: Pit vs bag				-0.063***
					(0.019)
	Storage: Traditional dibignet vs bag				0.016
					(0.039)
	Number of storage conservation activities[d]				0.003
					(0.016)
Market	Sale: Sale in nearest town vs village			0.015	0.029
				(0.018)	(0.018)
	Sale: Sale on plot/ house vs village			0.002	0.016
				(0.044)	(0.060)
	Sale: No sales vs sales in village			0.110***	0.088***
				(0.037)	(0.026)
Production problems & limitations to produce high quality (as perceived by the producer)	Climate			0.021	
				(0.030)	
	Pest			-0.027	
				(0.023)	
	Knowledge			0.012	
				(0.049)	
	Technology			0.185***	
				(0.060)	
	Storage			0.029	
				(0.062)	
	Soil			-0.001	
				(0.033)	
	Seeds			0.061**	
				(0.030)	
Location fixed effects		kebele	kebele	kebele	kebele
Agroecological zone dummies		yes	yes	yes	yes
No. of Obs.		1,090	1,090	1,090	1,071

Note: Marginal effects from GLM models are reported. Standard errors in parenthesis clustered at the district level. [a] This includes fertilizers, insecticides, herbicides and fungicides; [b] This includes mechanical herbicide and pesticide application, and plowing; [c] This refers to cutting, drying, piling, threshing, winnowing, packaging, and transport to piling, threshing, and/or storage; [d] This includes cleaning previous to storage and preparation of storage site

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Appendix A

Table A1: Survey questions to estimate food losses with the 'Self-reported method'

		Sum of survey questions: 'In the last planting season.... '
PRODUCER	**Loss expressed in weight**	a) what is the quantity of your harvest that was damaged (previous to post-harvest activities)? b) what is the quantity of good product that was not harvested (left in the field)? c) what is the quantity totally lost during post-harvest activities? d) what is the quantity damaged during post-harvest activities?
	Loss expressed in value	a) what is the value of your harvest that was damaged (previous to post-harvest activities)? b) what is the value of the quantity of good product that was not harvested (left in the field)? c) what is the value of your product totally lost during post-harvest activities? d) what is the value of your product damaged during post-harvest activities?
		Sum of the survey questions: 'Last month, and between the moment of purchase and sales of your product...'
MIDDLEMEN	**Loss expressed in weight**	a) Was is the quantity of your total purchase that got damaged during each of your post-harvest activities? b) Was is the quantity of your total purchase that got totally lost during each of your post-harvest activities?
	Loss expressed in value	a) Was is the value of your total purchase that got damaged during each of your post-harvest activities? b) Was is the value of your total purchase that got totally lost during each of your post-harvest activities?
		Sum of the survey questions: 'Last month, and between the moment of purchase and sales of your product...'
WHOLESALER	**Loss expressed in weight**	a) Was is the quantity of your total purchase that got damaged during each of your transformation activities? b) Was is the quantity of your total purchase that got totally lost during each of your transformation activities?
	Loss expressed in value	a) Was is the value of your total purchase that got damaged during each of your transformation activities? b) Was is the value of your total purchase that got totally lost during each of your transformation activities?

Table A2: Losses along the potato value chain in Ecuador

Level of the value chain				P method		S method		C method		A method	
				mean	std dev	mean	std dev	mean	std dev	mean	std dev
PRODUCER (N=287)	Left in the field	Weight of quantity left in the field	in kg	226.15^	1,250.83^	226.15	1,250.83	226.15^	1,250.83^	226.15^	1,250.83^
			% of total production	**0.67%^**	0.03^	**0.67%**	0.03	**0.67%^**	0.03^	**0.67%^**	0.03^
		Value of quantity left in the field	in USD	40.02^	194.13^	40.02	194.13	40.02^	194.13^	40.02^	194.13^
			% of value of total production	**0.55%^**	0.03^	**0.55%**	0.03	**0.55%^**	0.03^	**0.55%^**	0.03^
	Qualitative pre-harvest loss	Weight affected by quality deterioration	in kg	-		779.70	1,723.27	3,378.27	9,479.02	2,611.90	6,180.92
			% of total production			**5.01%**	0.13	**7.69%**	0.08	**8.43%**	0.17
		Value affected by quality deterioration	in USD	-		128.27	297.69	806.70	2,263.51	461.74	1,102.87
			% of value of total production			**3.40%**	0.09	**7.69%**	0.08	**6.18%**	0.13
	Qualitative and Quantitative post-harvest loss	Weight totally lost and affected by quality deterioration at post-harvest	in kg	-		492.67	1,072.99	2,321.71	8,279.38	2,409.36	12,308.30
			% of total production			**2.45%**	0.05	**4.46%**	0.10	**3.88%**	0.10
		Value totally lost and affected by quality deterioration at post-harvest	in USD	-		100.89	256.07	696.57	2160.64	550.70	2529.49
			% of value of total production			**2.28%**	0.06	**5.54%**	0.10	**3.93%**	0.10
TOTAL LOSS AT THE PRODUCER LEVEL			in kg	4145.65	15885.53	1,497.72	2,269.53	5926.13	14155.88	4982.47	13634.20
			% of total production	**11.84%**	0.16	**8.11%**	0.14	**12.82%**	0.14	**12.17%**	0.19
			in USD	989.95	3,793.33	269.18	434.27	1,543.29	3,661.19	1,007.46	2,754.94
			% of value of total production	**11.84%**	0.16	**6.22%**	0.11	**13.78%**	0.14	**10.03%**	0.16

Note: P= Price method; S= Self-reported method, C= Category method; A= Attribute method; obs= Number of observations; ^ Data are imputed from the 'S measurement'; Quantitative Loss = Total loss (product disappeared); Qualitative Loss= Product affected by quality deteriorations (product did not entirely disappear but quality is reduced)

Table A2: Losses along the potato value chain in Peru

Level of the value chain				P method mean	P method std dev	S method mean	S method std dev	C method mean	C method std dev	A method mean	A method std dev
PRODUCER (N=369)	Left in the field	Weight affected by quality deterioration at pre-harvest	in kg	348.39^	1,331.35^	348.39	1,331.35	348.39^	1,331.35^	348.39^	1,331.35^
			% of total production	**0.77%^**	0.02^	**0.77%**	0.02	**0.77%^**	0.02^	**0.77%^**	0.02^
		Value affected by quality deterioration at pre-harvest	in USD	56.47^	174.14^	56.47	174.14	56.47^	174.14^	56.47^	174.14^
			% of value of total production	**0.66%^**	0.02^	**0.66%**	0.02	**0.66%^**	0.02^	**0.66%^**	0.02^
	Qualitative pre-harvest loss	Weight affected by quality deterioration at pre-harvest	in kg	-		2,249.98	4,374.09	7,603.83	30,372.37	7,848.75	24,024.36
			% of total production			**6.24%**	0.11	**12.70%**	0.06	**16.26%**	**22.76%**
		Value affected by quality deterioration at pre-harvest	in USD	-		265.36	632.76	1,715.88	6,853.83	1,419.39	4,421.27
			% of value of total production			**3.42%**	0.08	**12.70%**	0.06	**13.03%**	**18.20%**
	Qualitative and Quantitative post-harvest loss	Weight totally lost and affected by quality deterioration at post-harvest	in kg	-		949.16	3,004.10	1,263.84	4,068.20	3,674.13	30,220.87
			% of total production			**2.37%**	0.05	**2.51%**	0.06	**3.36%**	**14.04%**
		Value totally lost and affected by quality deterioration at post-harvest	in USD	-		132.23	367.66	343.19	1027.08	782.12	6703.79
			% of value of total production			**1.51%**	0.04	**3.37%**	0.06	**3.10%**	**13.03%**
TOTAL LOSS AT THE PRODUCER LEVEL			in kg	7,998.07	19,046.68	3,547.54	6,947.70	9,216.06	32,955.29	11,522.87	38,725.77
			% of total production	**19.84%**	0.19	**9.38%**	0.13	**15.99%**	0.10	**19.62%**	0.26
			in USD	1,804.85	4,298.08	454.06	841.79	2,115.54	7,330.47	2,201.52	8,059.87
			% of value of total production	**19.84%**	0.19	**5.58%**	0.09	**16.73%**	0.11	**16.13%**	0.21

Note: P= Price method; S= Self-reported method, C= Category method; A= Attribute method; obs= Number of observations; ^ Data are imputed from the 'S measurement'; Quantitative Loss = Total loss (product disappeared); Qualitative Loss= Product affected by quality deteriorations (product did not entirely disappear but quality is reduced)

Table A3: Losses along the bean value chain in Guatemala

Level of the value chain				P method mean	P method std dev	S method mean	S method std dev	C method mean	C method std dev	A method mean	A method std dev
PRODUCER (N=431)	**Left in the field**	Weight affected by quality deterioration at pre-harvest	in kg	0.87^	2.20^	0.87	2.20	0.87^	2.20^	0.87^	2.20^
			% of total production	**1.16%^**	0.03^	**1.16%**	0.03	**1.16%^**	0.03^	**1.16%^**	0.03^
		Value affected by quality deterioration at pre-harvest	in USD	1.07^	2.72^	1.07	2.72	1.07^	2.72^	1.07^	2.72^
			% of value of total production	**1.01%^**	0.03^	**1.01%**	0.03	**1.01%^**	0.03^	**1.01%^**	0.03^
	Qualitative pre-harvest loss	Weight affected by quality deterioration at pre-harvest	in kg	-		1.88	5.71	7.20	13.00	17.56	38.34
			% of total production			**2.76%**	0.08	**5.56%**	0.05	**13.62%**	0.19
		Value affected by quality deterioration at pre-harvest	in USD	-		1.97	6.01	10.41	18.78	22.17	48.71
			% of value of total production			**2.26%**	0.06	**5.56%**	0.05	**11.99%**	0.17
	Qualitative and Quantitative post-harvest loss	Weight totally lost and affected by quality deterioration at post-harvest	in kg	-		4.72	9.77	7.93	28.99	6.37	25.89
			% of total production			**5.85%**	0.12	**6.08%**	0.13	**4.88%**	0.12
		Value totally lost and affected by quality deterioration at post-harvest	in USD	-		5.20	11.15	14.84	48.60	9.40	37.89
			% of value of total production			**4.45%**	0.09	**6.39%**	0.13	**4.97%**	0.12
TOTAL LOSS AT THE PRODUCER LEVEL			in kg	26.59	48.09	7.47	12.12	16.01	35.68	24.79	46.56
			% of total production	**16.72%**	0.18	**9.77%**	0.15	**12.80%**	0.15	**19.67%**	0.22
			in USD	38.42	69.48	8.24	13.61	26.31	60.40	32.64	62.22
			% of value of total production	**16.72%**	0.18	**7.72%**	0.12	**12.95%**	0.16	**17.97%**	0.20

Note: P= Price method; S= Self-reported method, C= Category method; A= Attribute method; obs= Number of observations; ^ Data are imputed from the 'S measurement'; Quantitative Loss = Total loss (product disappeared); Qualitative Loss= Product affected by quality deteriorations (product did not entirely disappear but quality is reduced)

Table A4: Losses along the maize value chain in Guatemala

Level of the value chain				P method mean	P method std dev	S method mean	S method std dev	C method mean	C method std dev	A method mean	A method std dev
PRODUCER (N=876)	Left in the field	Weight affected by quality deterioration at pre-harvest	in kg	3.76^	11.59^	3.76	11.59	3.76^	11.59^	3.76^	11.59^
			% of total production	**0.45%^**	1.33^	**0.45%**	0.01	**0.45%^**	1.33^	**0.45%^**	1.33^
		Value affected by quality deterioration at pre-harvest	in USD	1.26^	3.65^	1.26	3.65	1.26^	3.65^	1.26^	3.65^
			% of value of total production	**0.41%^**	1.18^	**0.41%**	0.01	**0.41%^**	1.18^	**0.41%^**	1.18^
	Qualitative pre-harvest loss	Weight affected by quality deterioration at pre-harvest	in kg	-		17.93	34.43	81.23	145.18	144.48	368.06
			% of total production			**3.89%**	0.09	**8.94%**	0.07	**15.86%**	0.20
		Value affected by quality deterioration at pre-harvest	in USD	-		5.58	11.70	34.51	61.68	32.92	83.59
			% of value of total production			**2.94%**	0.07	**8.94%**	0.07	**8.46%**	0.11
	Qualitative and Quantitative post-harvest loss	Weight totally lost and affected by quality deterioration at post-harvest	in kg	-		33.98	56.73	52.75	217.32	46.69	197.94
			% of total production			**5.50%**	0.10	**5.18%**	0.11	**4.15%**	0.09
		Value totally lost and affected by quality deterioration at post-harvest	in USD	-		11.53	19.23	22.30	89.64	20.54	86.53
			% of value of total production			**4.38%**	0.08	**5.41%**	0.11	**4.58%**	0.10
TOTAL LOSS AT THE PRODUCER LEVEL			in kg	178.73	546.50	55.67	70.13	137.74	278.79	194.93	442.38
			% of total production	**14.10%**	0.16	**9.84%**	0.14	**14.58%**	0.13	**20.46%**	0.21
			in USD	75.93	232.17	18.37	24.22	58.07	119.33	54.72	125.43
			% of value of total production	**14.10%**	0.16	**7.72%**	0.12	**14.76%**	0.15	**13.45%**	0.14

Note: P= Price method; S= Self-reported method, C= Category method; A= Attribute method; obs= Number of observations; ^ Data are imputed from the 'S measurement'; Quantitative Loss = Total loss (product disappeared); Qualitative Loss= Product affected by quality deteriorations (product did not entirely disappear but quality is reduced)

Table A5: Losses along the bean value chain in Honduras

Level of the value chain				P method mean	P method std dev	S method mean	S method std dev	C method mean	C method std dev	A method mean	A method std dev
PRODUCER (N=650)	Left in the field	Weight affected by quality deterioration at pre-harvest	in kg	3.95^	11.59^	3.95	11.59	3.95^	11.59^	3.95^	11.59^
			% of total production	**0.98%^**	0.03^	**0.98%**	0.03	**0.98%^**	0.03^	**0.98%^**	0.03^
		Value affected by quality deterioration at pre-harvest	in USD	3.37^	9.77^	3.27	9.77	3.37^	9.77^	3.37^	9.77^
			% of value of total production	**0.93%^**	0.03^	**0.93%**	0.03	**0.93%^**	0.03^	**0.93%^**	0.03^
	Qualitative pre-harvest loss	Weight affected by quality deterioration at pre-harvest	in kg	-		9.42	37.45	46.81	88.39	74.73	181.84
			% of total production			**2.35%**	0.09	**8.06%**	0.05	**14.12%**	0.22
		Value affected by quality deterioration at pre-harvest	in USD	-		6.34	25.89	42.06	79.42	57.23	138.76
			% of value of total production			**1.90%**	0.07	**8.06%**	0.05	**12.01%**	0.19
	Qualitative and Quantitative post-harvest loss	Weight totally lost and affected by quality deterioration at post-harvest	in kg	-		13.10	41.16	16.20	69.82	35.48	185.09
			% of total production			**2.92%**	0.09	**4.23%**	0.11	**4.67%**	0.11
		Value totally lost and affected by quality deterioration at post-harvest	in USD	-		8.95	28.96	28.40	71.52	29.51	145.30
			% of value of total production			**2.40%**	0.08	**6.35%**	0.11	**4.62%**	0.11
TOTAL LOSS AT THE PRODUCER LEVEL			in kg	129.69	392.89	26.47	62.58	66.96	117.30	114.16	266.35
			% of total production	**17.39%**	0.22	**6.25%**	0.14	**13.27%**	0.12	**19.77%**	0.25
			in USD	116.53	353.04	18.56	44.41	73.73	123.74	90.01	207.21
			% of value of total production	**17.39%**	0.22	**5.23%**	0.12	**15.34%**	0.12	**17.56%**	0.22

Note: P= Price method; S= Self-reported method, C= Category method; A= Attribute method; obs= Number of observations; ^ Data are imputed from the 'S measurement'; Quantitative Loss = Total loss (product disappeared); Qualitative Loss= Product affected by quality deteriorations (product did not entirely disappear but quality is reduced)

Table A6: Losses along the maize value chain in Honduras

Level of the value chain				P method mean	P method std dev	S method mean	S method std dev	C method mean	C method std dev	A method mean	A method std dev
PRODUCER (N=988)	Left in the field	Weight affected by quality deterioration at pre-harvest	in kg	12.03^	41.31^	12.03	41.31	12.03^	41.31^	12.03^	41.31^
			% of total production	**1.02%^**	0.03^	**1.02%**	0.03	**1.02%^**	0.03^	**1.02%^**	0.03^
		Value affected by quality deterioration at pre-harvest	in USD	3.68^	11.47^	3.68	11.47	3.68^	11.47^	3.68^	11.47^
			% of value of total production	**0.98%^**	0.03^	**0.98%**	0.03	**0.98%^**	0.03^	**0.98%^**	0.03^
	Qualitative pre-harvest loss	Weight affected by quality deterioration at pre-harvest	in kg	-		37.84	78.01	93.20	276.62	96.84	369.77
			% of total production			**5.52%**	0.12	**7.19%**	0.07	**7.11%**	0.15
		Value affected by quality deterioration at pre-harvest	in USD	-		11.04	24.77	32.50	96.45	31.33	120.01
			% of value of total production			**4.73%**	0.11	**7.19%**	0.07	**6.60%**	0.14
	Qualitative and Quantitative post-harvest loss	Weight totally lost and affected by quality deterioration at post-harvest	in kg	-		28.74	76.27	80.84	236.10	89.32	562.55
			% of total production			**3.41%**	0.09	**8.47%**	0.14	**7.81%**	0.14
		Value totally lost and affected by quality deterioration at post-harvest	in USD	-		8.58	21.30	29.24	64.05	30.18	170.86
			% of value of total production			**3.16%**	0.09	**8.48%**	0.14	**7.83%**	0.14
TOTAL LOSS AT THE PRODUCER LEVEL			in kg	284.26	767.32	78.61	130.64	186.08	402.77	198.19	730.11
			% of total production	**17.41%**	0.21	**9.95%**	0.16	**16.69%**	0.16	**15.95%**	0.20
			in USD	99.12	267.55	23.30	38.33	65.43	124.38	65.19	225.24
			% of value of total production	**17.41%**	0.21	**8.87%**	0.15	**16.64%**	0.16	**15.41%**	0.19

Note: P= Price method; S= Self-reported method, C= Category method; A= Attribute method; obs= Number of observations; ^ Data are imputed from the 'S measurement'; Quantitative Loss = Total loss (product disappeared); Qualitative Loss= Product affected by quality deteriorations (product did not entirely disappear but quality is reduced)

Table A7: Losses along the teff value chain in Ethiopia

Level of the value chain				P method		S method		C method		A method	
				mean	std dev	mean	std dev	mean	std dev	mean	std dev
PRODUCER (N=1186)	Left in the field	Weight affected by quality deterioration at pre-harvest	in kg	0.00^	0.01^	0.00	0.01	0.00^	0.01^	0.00^	0.01^
			% of total production	**0.00%^**	0.00^	**0.00%**	0.00	**0.00%^**	0.00^	**0.00%^**	0.00^
		Value affected by quality deterioration at pre-harvest	in USD	0.02^	0.52^	0.02	0.52	0.02^	0.52^	0.02^	0.52^
			% of value of total production	**0.00%**	0.00	**0.00%**	0.00	**0.00%**	0.00^	**0.00%**	0.00^
	Qualitative pre-harvest loss	Weight affected by quality deterioration at pre-harvest	in kg	-		8.89	30.92	40.77	46.83	238.69	539.29
			% of total production			**2.34%**	0.08	**6.39%**	0.04	**17.07%**	0.29
		Value affected by quality deterioration at pre-harvest	in USD	-		11.25	40.78	63.32	72.74	64.23	157.66
			% of value of total production			**1.81%**	0.06	**6.39%**	0.04	**6.63%**	0.13
	Qualitative and Quantitative post-harvest loss	Weight totally lost and affected by quality deterioration at post-harvest	in kg	-		18.44	16.17	16.24	70.65	42.68	166.45
			% of total production			**4.52%**	0.06	**2.28%**	0.08	**7.03%**	0.15
		Value totally lost and affected by quality deterioration at post-harvest	in USD	-		28.98	26.92	34.65	112.10	26.78	107.56
			% of value of total production			**4.45%**	0.06	**3.10%**	0.08	**4.77%**	0.12
TOTAL LOSS AT THE PRODUCER LEVEL			in kg	47.59	94.88	27.35	36.39	57.02	90.10	281.41	555.65
			% of total production	**8.69%**	0.12	**6.86%**	0.11	**8.67%**	0.09	**19.76%**	0.30
			in USD	73.91	147.36	40.24	51.36	97.98	143.19	91.03	190.62
			% of value of total production	**8.69%**	0.12	**6.26%**	0.09	**9.49%**	0.09	**9.02%**	0.14

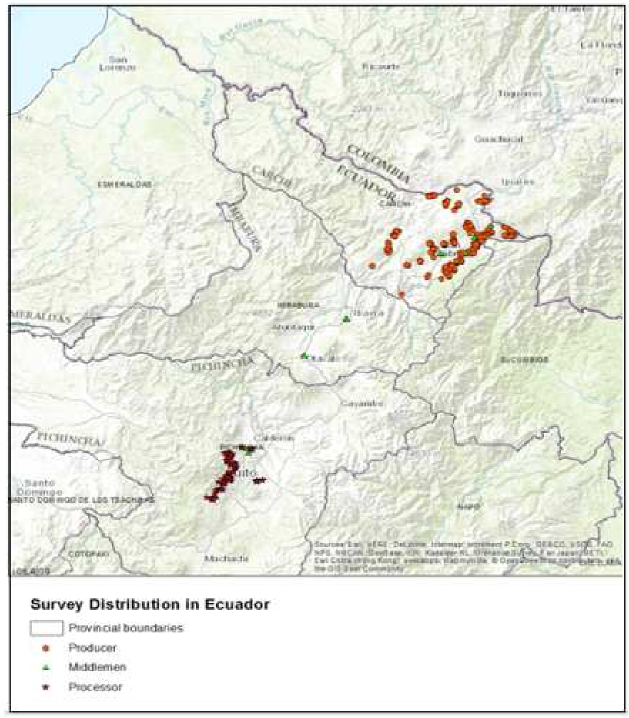
Note: P= Price method; S= Self-reported method, C= Category method; A= Attribute method; obs= Number of observations; ^ Data are imputed from the 'S measurement'; Quantitative Loss = Total loss (product disappeared); Qualitative Loss= Product affected by quality deteriorations (product did not entirely disappear but quality is reduced); The official exchange rate in the year of the survey is 22.40 Birr/ USD (National Bank of Ethiopia)

Appendix B

The countries in which we work and the distribution of the surveys were:

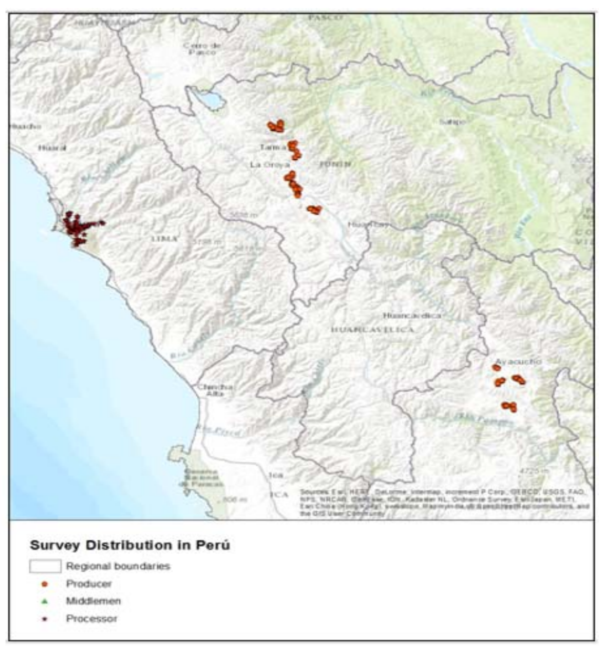
1. Ecuador: We collected 631 surveys (302 farmers, 182 middlemen, and 147 wholesale buyers) in the provinces of Carchi, Imbabura and Pichincha; the following map shows distribution.

ECUADOR

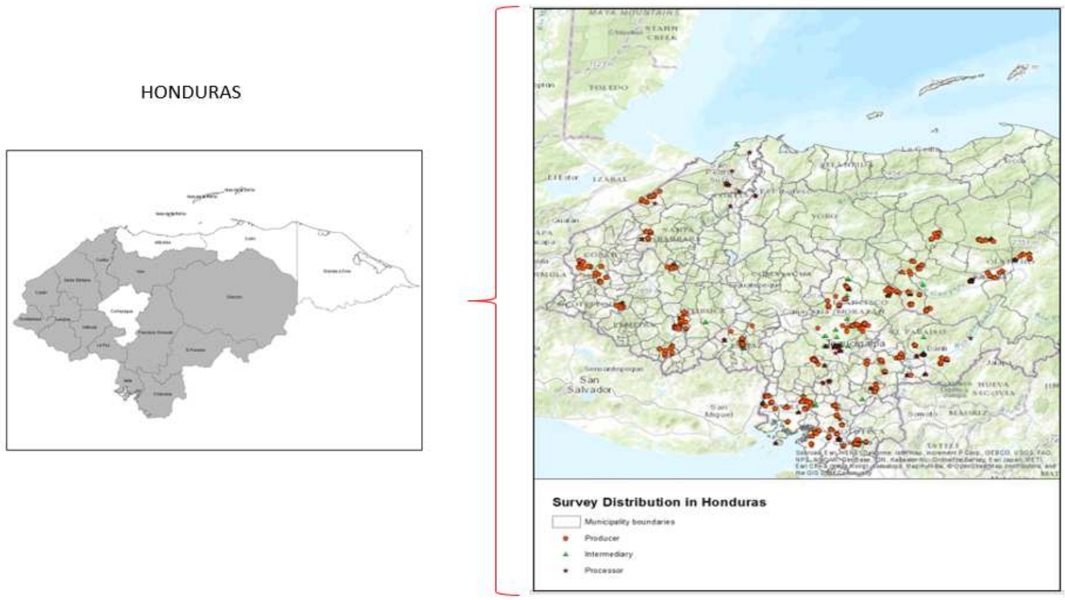


2. Peru: We collected 534 surveys (411 farmers, 77 middlemen, and 139 wholesale buyers) in the departments of Ayacucho, Junín and Lima; the following map shows the distribution.

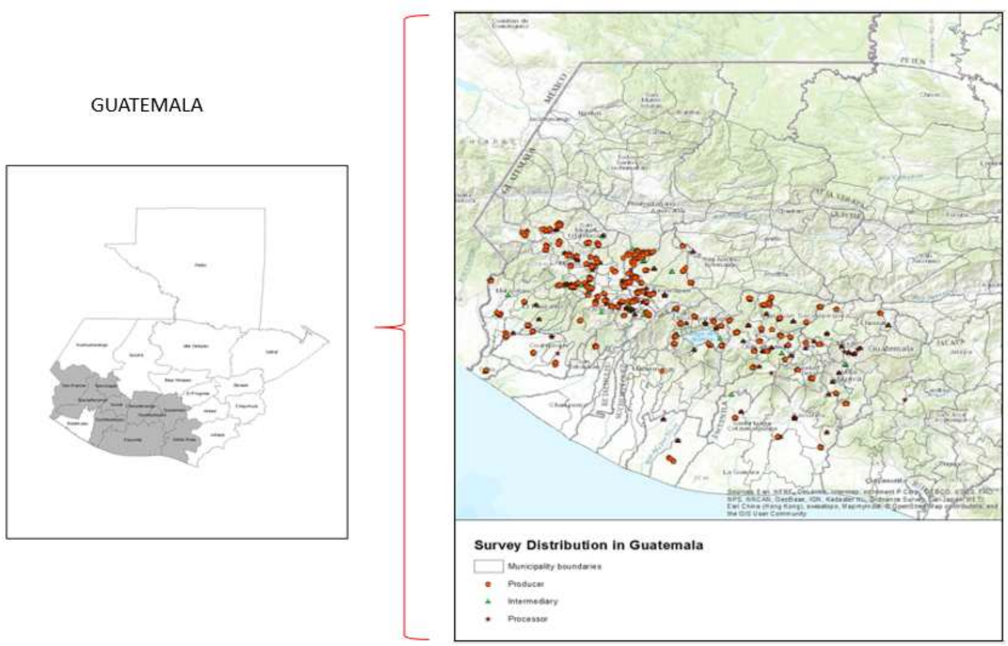
PERU



3. Honduras: We collected 1777 surveys (1155 farmers, 377 middlemen, and 245 wholesale buyers) in the departments of Choluteca, El Paraiso, Francisco Morazán, Intibucá, La Paz, Lempira, Ocotepeque, Olancho, Santa Barbara, Valle, Cortes, Copan and Yoro; the following map shows the distribution.



4. Guatemala: We collected 1758 surveys (1209 farmers, 325 middlemen, and 224 wholesale buyers) in the departments of Solola, Quetzaltenango, Totonicapan, San Marcos, Guatemala, Sacatepequez, Chimaltenango and Escuintla; the following map shows the distribution.



5. Ethiopia We collected 1203 surveys for farmers in the regions of Oromia and Amhara; the following map shows the distribution.