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Food loss and waste accounting: the case of the Philippine food supply chain

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Abstract. In recent years, the interest in food loss and waste has been gaining momentum from researchers and policy-makers. Much of the attention on the matter is centered in industrialized countries, creating a knowledge gap within developing countries, among which is the Philippines. This lack of information impedes the country-level response in solving the issue, whose implications extend to food and nutrition security, productivity, and resource use. For this reason, our paper estimates the food loss and waste levels in the Philippine food supply chain of rice, corn, and banana commodities. We were first to identify the percentage accumulation of food loss and waste in each stage of the food supply chain and translated such portions into edible food volumes initially intended for human consumption. Our findings revealed that between one-seventh to one-fifth of edible rice, corn, and banana quantities are lost/wasted in their respective food supply chains. For each of the commodities analyzed, the principal activities responsible for the problem are drying, dehanding, and harvesting, respectively. Our results suggest the following for policy intervention and research: establish an agreed-upon food loss and waste definition; calibrate interventions at the level of the food supply chain; follow a supply chain system approach in reducing the problem; and determine an acceptable level of loss/waste.

Keywords: Food loss and waste, Food supply chain, Philippines.
JEL code: Q13, Q18.

1. INTRODUCTION

The widespread attention placed on losses is not of recent concern. It has been first expressed as one of FAO's organizational mandates during its establishment in 1945 (Parfitt *et al.,* 2010). The matter was highlighted again during the Seventh Session of the United Nations General Assembly in 1975 when they aimed to halve postharvest losses by 1985 (Fabi & English, 2019). Long after, the food crisis in 2007-2008 paved the renewed interest in addressing the problem (Fabi *et al.,* 2021). By 2011, the issue was better realized by releasing the first global estimate of FLW, where about one-third of the food produced for human consumption is lost or wasted (Gustavsson *et al.*, 2011). Subsequently, the international community recognized the concerning levels of food loss and waste (FLW) in the Sustainable Development Goals (SDGs) and stated its reduction goal in Target 12.3.

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The broad interest in FLW is due to its implications transcending the issue of unrealized physical food quantities. For example, the FAO (2017) reports that recovering or minimizing food outflow from the chain can increase productivity, promote food and nutrition security, and minimize negative environmental impacts. Further, there are also moral overtones surrounding the problem (Gjerris, 2020), given that 155 million people globally are acutely food insecure (FSIN & GNAFC, 2021). However, to design an effective policy intervention, there is a need to establish empirical information on the magnitude and causes of FLW generation. Moreover, at the country level, there is a need to strengthen efforts to understand the problem at a disaggregate scale, particularly on the different commodity food supply chains (FSCs).

Currently, limitations to an evidence-based policymaking process in this field exist, which also constraints the synchronized global effort to reduce FLW. For example, Xue *et al.* (2017) identified three significant biases in the literature: first, the analyses are more concentrated in industrialized countries; second, over half of the publications relied on secondary data, with some authors using outdated data; and third, studies are abundant at the retail and consumption stages.

These biases imply that information on the issue is limited in developing countries such as the Philippines. In this country, the potential benefits of FLW reduction on food security and poverty reduction are vital if we consider that 64% of the Filipino population is chronically food insecure (IPC, n.d.). Further, two of the most important FSC actors, farmers and fishermen, are consistently classified as the country's poorest groups. Moreover, in the Philippines, commodity losses from harvesting to distribution are reported to reach as high as 50% (Mopera, 2016). The FAO (2019) notes that this is a manifestation of the significant constraints actors face in performing their activities. Collectively, these imply that the recovery or prevention of food outflow from the chain has great potential in feeding and improving the livelihoods of people in the country.

Despite the potential positive impacts of FLW reduction on the Philippines' sustainable development, studies on the matter lack. Following Gustavsson *et al.* (2011), we considered FLW at the main stages of the FSC, namely the agricultural production, postharvest handling and storage, processing and packaging, distribution, and consumption. Further, we used the concept of FLW of Gustavsson *et al.* (2011) to understand loss/waste in the all stages of the rice, corn, and banana FSCs. The selected commodities are three of the most important crops in the Philippines, creating significant implications on the country's agricultural sector. Moreover, owing to the methodological elements we used in this paper, our estimations can be considered as the first national accounting of edible food reductions initially allocated for human consumption across all stages of the FSC in selected Philippine commodities. We also included the consumption stage in our FSC analysis, a level of investigation where knowledge on the problem is lacking. Finally, through an extensive review of relevant literature, we attempt to explain the causes of FLW generation to recognize the actions or decisions that lead to the problem.

As previously mentioned, we used the definition offered by Gustavsson *et al.* (2011), where food loss refers to the reduction in food quantities from the activities of agricultural production until the point prior to retail, while that of food waste is found at the retail and consumption stages. The terms are further characterized such that only edible portions and food shares for human consumption are considered FLW (Gustavsson *et al.,* 2011). We followed the interpretation offered by Gustavsson *et al.* (2011) because we adopted their methodology in estimating the magnitudes of FLW. This choice was important prior to our assessment because it was crucial to operationalize the elements characterizing the concepts.

The literature on the subject, however, articulates that there is no fixed definition and that various entities provide different interpretations depending on their objective of assessing the issue (Chaboud & Daviron, 2017; FAO, 2014). As such, publications on the matter have varying illustrations and usage of the terms (FAO, 2014; Parfitt *et al.,* 2010; Ishangulyyev *et al.,* 2019; Chaboud & Daviron, 2017; Garrone *et al*., 2014; Papargyropoulou *et al*., 2014; Galli *et al.,* 2019; von Massow *et al*., 2019).

To apply the approach of Gustavsson *et al.* (2013), we conducted an extensive literature review to gather the potential variables and organized them into a matrix to facilitate the data selection and estimation of FLW. This effort was due to a lack of systematized information from official sources. It also reinforces the need for more research and information on the issue.

The paper is organized as follows: Section 2 presents the methodology we adopted for this study and the requisite dataset for the estimations, Section 3 presents and discusses the results, and Section 4 concludes.

2. METHODOLOGY AND DATA

2.1 Estimation Approaches

Gustavsson *et al.* (2013) offered two approaches to estimating FLW: the percentage accumulation of loss/waste in the FSC and the resulting volumes generated at

Table 1. Estimation guide for the percentage loss/waste accumulation in the FSC.

Agricultural Production (AP)	Postharvest Handling and Storage (PHS)	Processing and Packaging (PP)	Distribution (D)	Consumption (C)
%AP	%PHS× (1-%AP)	%PP× (1-%AP)× (1-%PHS)	%D× (1-%AP)× (1-%PHS)× (1-%PP)	%C×(1-%AP) ×(1-%PHS) ×(1-%PP) ×(1-%D)

Note: %AP, %PHS, %PP, %D, and %C=weight percentages per FSC stage.
Source: Gustavsson *et al.*, 2013.

each stage. Although the two methods show the magnitude of the problem, we opted to use both means because the elements in each estimation bring different realizations. The first one shows the percentage accumulation of FLW as food moves through each stage of the FSC. With this information, we can determine the total portion of the commodity that was lost/wasted. In comparison, the second one reflects the volumes of FLW at each stage of the chain. In other words, it translates the figures into actual food volumes that could have been utilized in the country. Indirectly, the volume estimates can also show the significance of the commodity as food for the country.

Table 1 presents the details of the first approach. To illustrate the use of this information and formula, let us start with a hypothetical agricultural production equal to 100. At this stage, the loss/waste is equal to %AP. At the postharvest handling and storage stage (PHS), the percentage of loss/waste (%PHS) is computed out of the remaining share of production at the preceding stage (1-%AP). The same approach is used in the subsequent stages.

For the calculation of the FLW volumes, we used the formulae presented in Table 2 and based our estimations on the mass flow model (Figure 1). This model presents in a diagram the domestic supply quantities and utilization elements that provide the quantity of food available for consumption.

There are three columns in Table 2. The first one lays out the stages of the FSC. The second and third columns present the formulae we followed in calculating for the FLW volume of cereal and non-cereal commodities, respectively. In each FSC stage, we followed a two-step approach in estimating its FLW volume.

The first step of the estimation process calculates the loss/waste in its entirety. These elements are denoted by the index *W* in Table 2. In other words, it relates to the first aspect of the FLW definition of Gustavsson *et al.* (2011), where it is the total reduction of food quantities in the FSC. The second step accounts for the peculiarity of FLW such that only the shares for human consumption (*HC*) and edible portion (*E*) are considered.

Using the PHS stage as an example, we first determined the volume of FLW at PHS (PHS_W) by multiplying the percentage loss/waste (%PHS) at this stage by the total production (A).

The second part of the estimation adjusts the volume of FLW (in our previous example, PHS_W) to fit the FLW definition of intention for human consumption (PHS_{HC}) and edibility (PHS_E). We adjusted the first-level estimate for cereals using allocation factors (AF) and for non-cereal items with conversion factors (CF).

The differing factor adjustments between cereal and non-cereal commodities (AF and CF) come from the nature of their utilization and mass flows model data. According to Gustavsson *et al.* (2013), a significant portion of cereal production is adopted for means other than human consumption. For this reason, we used the allocation factor to capture the share of cereals appropriated for human consumption. In contrast, for non-cereal commodities, the relevant aspect is edibility, which we estimated with the use of the conversion factors. We recognize that cereals have portions which are inedible. However, the data on rice and corn are already in their milled and grain forms, respectively, thereby rendering the use of conversion factors irrelevant.

As seen in Table 2, there are other nuances in the formulae used for different commodity types and FSC stages. For cereals, the difference comes from the specificities of the individual FSCs. In the estimation of rice, for example, we only used element "Food" (denoted by *J*) in the final three FSC stages because all rice grains deemed as food are used in milled form (Gustavsson *et al.*, 2013). For corn, we used elements "Processing" (denoted by *H*) and "Milled food" (denoted by *K*) in the last FSC stages because the commodity can be used as food both in its grain and milled forms.

On the other hand, for the last three stages of non-cereal commodities, we used "Processing" (denoted by *H*) and the sub-elements of "Food" (denoted by *J*). The sub-elements of "Food" could be in either "Fresh" (denoted by *K*) or "Processed" (denoted by *L*) forms. As previously mentioned, *H* refers to the quantities of

Table 2. Estimation guide for the volume of FLW generated at each FSC stage and by crop.

FSC Stage	Cereals	Non-cereals
Agricultural Production (AP)	$AP_W = \frac{\%AP}{1-\%AP} \times A$ $AP_{HC} = AP_W \times AF$	$AP_W = \frac{\%AP}{1-\%AP} \times A$ $AP_E = AP_W \times CF$
Postharvest Handling and Storage (PHS)	$PHS_W = \%PHS \times A$ $PHS_{HC} = PHS_W \times AF$	$PHS_W = \%PHS \times A$ $PHS_E = PHS_W \times CF$
Processing and Packaging (PP)	Rice: $PP_R = \%PP \times J$ Corn: $PP_C = \%PP \times (H + K)$	$PP_W = \%PP \times (H + L)$ $PP_E = PP_W \times CF$
Distribution (D)	Rice: $D_R = \%D \times (J - PP_R)$ Corn: $D_C = \%D \times (H + K - PP_C)$	$D_{F,W} = \%D_F \times K$ $D_{F,E} = D_{F,W} \times CF$ $D_{P,W} = \%D_P \times (H + L - PP_W)$ $D_{P,E} = D_{P,W} \times CF$ $D_{total} = D_{F,E} + D_{P,E}$
Consumption (C)	Rice: $C_R = \%C \times (J - PP_R - D_R)$ Corn: $C_C = \%C \times (H + K - PP_C - D_C)$	$C_{F,W} = \%C_F \times (K - D_{F,W})$ $C_{F,E} = C_{F,W} \times CF$ $C_{P,W} = \%C_P \times (H + L - PP_W - D_{P,W})$ $C_{P,E} = C_{P,W} \times CF$ $C_{total} = C_{F,E} + C_{P,E}$

Note: %AP, %PHS, %PP, %D, and %C=weight percentages per FSC stage, A=Production, H=Processing, J=Food, K=Fresh/milled food, L=Processed food, sub-components of Food (J) = K and L; sub-scripts: W=Total FLW, HC=Human consumption, E=Edible portion, F=Fresh food, P=Processed food, total=fresh + processed FLW.
Source: Gustavsson *et al.*, 2013.

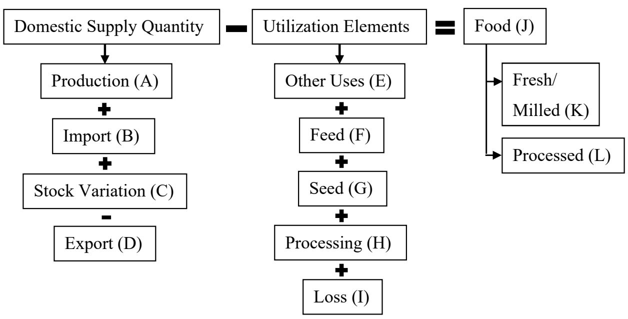

Figure 1. The mass flows model. Source: Gustavsson *et al.*, 2013.

the commodity that are used as raw material to manufacture food products, while L indicates the quantity of the commodity that is consumed in its non-fresh form. Moreover, since non-cereals can be consumed in fresh and processed forms, we separated the calculations of FLW according to its product form. This aspect was considered in the distribution and consumption stages, since the differentiation of the product materializes after the processing and packaging stage. Only after calculating the loss/waste between the two product forms (D_F and C_F for fresh; D_P, C_P for processed) we can estimate the total loss/waste generated for the distribution and consumption stages (D_{total} and C_{total}).

2.2. Data

Gustavsson *et al.* (2013) illustrated the FSC as a five-stage succession of activities, starting from production, postharvest handling and storage, processing and packaging, distribution, and consumption. To estimate the FLW generated at each stage, we first collected the weight percentages of loss/waste at each point in the FSC for all relevant commodities in the Philippines. We found this information through an extensive online search of studies, reports, and other pertinent publications of various researchers and institutions such as the United Nations Industrial Development Organization (UNIDO), Philippine Center for Postharvest Development and Mechanization (PhilMech), and Philippine Statistics Authority (PSA). We compiled all data and entered them into a matrix to analyze the information we had at hand. Upon assessing our matrix, we selected our data sources based on two grounds: data reliability and ability to reflect a relatively full picture of the FSC. It was also vital that we minimized the number of sources for commodity loss/waste weight percentages because we recognize that their methods and contexts differ.

This first stage of data gathering was the most laborious and limiting in terms of the number of commodities we can analyze for our study. Because of data availability and reliability issues and guided by the 2017 PSA publication on the food commonly consumed in the Philippines, we ultimately selected rice, corn, and banana for the study.

After establishing the food items for the study, we searched for their conversion and allocation factors using the same approach as the loss/waste weight percentages. As previously mentioned, these two factors align the initial FLW volume estimates with the definition offered by Gustavsson *et al.* (2011).

Another requirement for the calculations was the construction of the mass flows model. Primarily, it includes domestic supply and utilization elements. Concerning domestic supply, we collected information on production, import, stock variation, and export. As for the utilization elements, we gathered data on non-food uses, feed, seed, processing, and loss. Depending on the food category, we divided the food quantities into fresh and processed (non-cereals) and milled and feed (cereals). We determined the fresh food quantities for non-cereal commodities using the information on the portion of food utilized as fresh, which we also found through an online search. Finally, we identified milled food using the minimum main product recovery during the milling process.

There were two potential data sources for the mass flows model. Ultimately, we used the 2017 PSA data on Supply and Utilization Accounts because of the persistent value discrepancies in the processing parameter of FAOSTAT's Food Balance Sheet. Nonetheless, we had to adjust the PSA data to fit our methodological requirements. The first modification entailed the disaggregation of the processing data to capture the processed food quantities from the total value of the parameter, which includes non-food shares. For this, we took the prescribed proportions from PSA's measurement of the parameter. Our second adjustment was to separate the feeds and loss (or waste) into two parameters. Because there was no PSA guide to isolate the two, we took the proportions of each from FAOSTAT data and applied them to our PSA data. Lastly, we also assumed a value of one for the export parameter because PSA did not indicate the exact figure.

The mass flows model was also relevant in completing the loss/waste weight percentages for the PHS stage. According to Gustavsson *et al.* (2013), the element "loss" represents the food outflow for the said stage. For this, we took the portion of loss from the sum of production, import, and stock variation to extract the PHS weight percentage.

Of all the secondary data collected, the loss/waste weight percentages were highly influential in the FLW volume estimation. Some FSC stages have multiple activities, implying multiple loss/waste weight percentages per stage. Instead of adding the weight percentages, we calculated the FLW generated by each activity and deducted it from the succeeding activities within a stage.

Specifically for bananas, we modified its FLW volume estimation by following the data on banana loss/waste weight percentages. This meant a reorganization of the banana FSC such that distribution preceded the processing and packaging stage. As a result, we used the mass flows elements for processing (H) and food (J) in the calculation. At the processing and packaging stage, we deducted the FLW volume estimate from distribution activities. Lastly, we only used the fresh food formula for the consumption stage because of the lack of loss/waste weight percentage data for the processed food consumption of bananas.

3. RESULTS AND DISCUSSION

Our estimated total FLW, both in percentage terms and million metric tons (MT), are shown in Table 3. The largest share is generated in the banana FSC, followed by that of rice and corn. In terms of volume, rice has the highest FLW due to its role as a staple crop in the Philippines and, therefore, has the highest quantities of food in the supply chain. In comparison, corn and banana have less in terms of volume.

Presented in Figure 2 below is the total estimated FLW shares of all FSC stages of rice, corn, and banana commodities. From this figure, we can note that all stages contribute to the total FLW produced in each FSC. However, the critical stages are crop-specific. In particular, the critical loss points are processing and packaging in rice, agricultural production for corn, and distribution for bananas.

In deconstructing FLW figures, the FAO (2019) uses the term critical loss points to refer to the areas in the

Table 3. Total estimated FLW in the Philippine FSC by commodity.

Commodity	Percentage FLW	Volume FLW (million MT)
Rice	18.10	2.3
Corn	14.69	0.246
Banana	20.05	0.854

Source: authors' calculation.

FSC where food loss and waste levels are highest. Thus, directing the reduction efforts at these sites might have the most impact on food security and economic returns (FAO, 2019). In other words, by using the critical loss points as guides in policy formulation, we might recover the most food quantities and incomes we once lost from the FSC.

3.1 Rice

The literature on rice postharvest losses dictates a varied set of estimates and the extent of FSC stages covered. Some studies report a wide range of losses, such as Parfitt *et al.* (2010), who noted that rice losses in the Philippines are between 10-37%. Others state a more definite estimate, like Manalili *et al.* (2015), who claim that the average total loss incurred from harvesting up to milling is 15%. In comparison with these figures, it may seem that our total rice loss estimate of 18.10% does not deviate much from the two studies. However, because of the non-existence of a standard accounting method for FLW, our FSC coverage and estimation approach differ. In turn, this influences the results we offer from our analysis.

Deconstructing the processing and packaging stage, the critical loss point of rice, our estimates indicate that drying and milling activities are the primary sources of FLW. Of these two, drying generates the highest share at 30.67%, followed by milling at 27.19%. In volume terms, these portions respectively equate to 727,030 MT and 644,720 MT of rice loss. Confirming our results, Mopera (2016) reports that the two sub-stages of processing and packaging are the problematic areas in the rice FSC. However, she reported higher shares for the two, at 36% and 34%, respectively (Mopera, 2016).

There are several causes of drying losses. Manalili *et al.* (2015) point to low-quality equipment, improper use of machinery, and unfavorable drying conditions as the contributory causes of loss. These may indicate that drying losses are merely a result of the inappropriate adoption of machinery. Yet, there is another potential source of FLW for rice. The traditional method of sun drying, which is still prevalent in the country, can decrease grain quality and even cause the grain to crack (Mopera, 2016). Also, laying the grains on the ground creates difficulty in complete grain collection after drying (de Padua, 1999). Even though actors often express sun-drying as a low-cost production option, ultimately, they might receive a decreased income since low-quality grains command low market prices (Mopera, 2016).

In turn, improperly dried grains that enter the milling process will have a lower milling recovery (Chapungco *et al.*, 2008). This fact means that the expected quantity of milled rice was not met and lost instead. Aggravating the issue of grain recovery rate is the prevalent

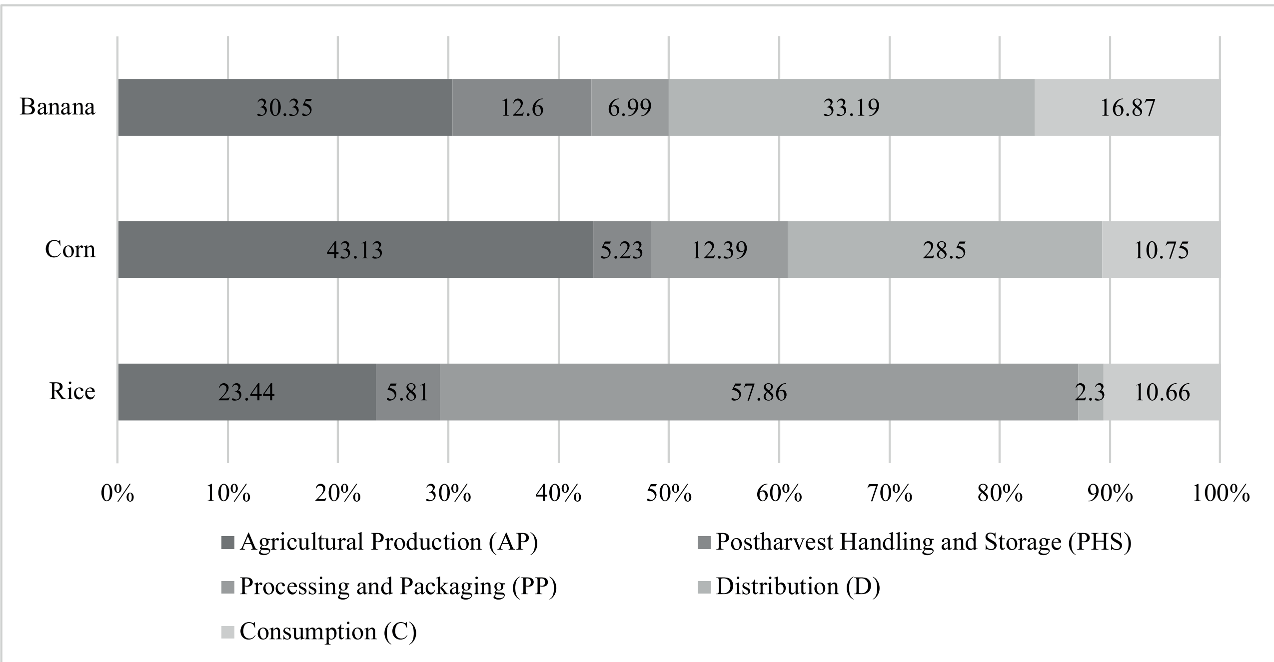

Figure 2. Total estimated FLW shares in each FSC stage by commodity. Source: authors' calculation.

use of dated milling equipment in the country (OECD, 2017). Besides loss generation, these two factors can also affect the marketability of low-quality milled rice, since Filipinos, regardless of social status, prefer to eat good quality rice (eds. Manilay and Frio, 1985 cited in Manalili *et al*., 2015).

Although less critical than processing and packaging in the FSC of rice, the agricultural production stage also has a considerable level of loss (502,810 MT). At this stage, harvesting and threshing are the main activities and contributors to FLW generation. Respectively, the two activities contribute 11.22% and 11.79% shares of total rice loss. When translated into volume, these two activities amount to 235,100 MT and 258,440 MT of rice loss. Some reported causes for harvesting losses are the natural separation of the grain from the panicle, grain spillage, and unharvested panicles, which can be an intentional labor practice for personal gain (UNIDO, 2012). On the other hand, the accumulation of loss during rice threshing can be caused by machine inefficiency. This situation pertains to mixing grains with the chaffs or the blending of partially threshed panicles with the completed ones (UNIDO, 2012).

In contradiction with our results, a study on the perception of loss generation revealed that farmers view harvesting activity as the primary source of loss (Dela Cruz & Calica, 2016). By focusing their assessment on actors' perceptions, Dela Cruz and Calica (2016) included social and cultural practices that are usually overlooked in analyzing commodity losses. However, when they compared their results against a previous actual loss assessment as a validation measure, it revealed drying as the critical activity of loss. They offered three explanations for such difference: first, the recall of their farmer-respondents was based on the past two cropping seasons that were affected by two strong typhoons that hit the country; second, harvesters intentionally leave portions of crops for gleaners; and third, farmers might be shifting the product forms they sell (from dried grains to wet grains) (Dela Cruz & Calica, 2016).

The study of Dela Cruz and Calica (2016) is important in understanding the complexities of FLW. First, it shows us that changing the approach to analyzing the problem yields different realizations that do not negate one for the other. Second, the inclusion of the interplay of society and culture, which affects the decisions of FSC actors, might provide a profound realization behind FLW generation. For example, the intentional leaving of grains at the field for gleaners might reflect altruism or other tacit relationships and agreements in the community rather than farmer inefficiency or carelessness. Finally, the omission of performing an activity may not impact the FLW levels for a stage or an actor but will do so for the latter ones.

Our estimation for the rice consumption stage revealed that Filipino households waste 252,630 MT of rice. In 2018, the Philippine Family Income and Expenditure Survey showed that the bottom three income classes in the country spend about 58% of their income on food and about 22% of which they spent on bread and cereal (PSA, 2020). The constancy of rice in a typical Filipino diet reflects its relative importance in food expenditure. Further, since there is a consumer preference for good quality rice (eds. Manilay & Frio, 1985 cited in Manalili *et al*., 2015), which commands a higher market price, the unrealized economic loss from a seemingly inconsequential rice wastage might be considerable.

3.2 Corn

Comparing rice with corn, the other cereal commodity in our study, we can note that the total FLW generated in the entire supply chain is a little below the estimate for rice, at 3.41 percentage points. However, when translated into volume, the corn FLW only amounts to 246,400 MT. The observable similarities in rice and corn supply chain activities might lead one to assume that the accrual of losses should be nearly level. However, the significant disparity exhibited by the two crops primarily comes from the definition we used for the study, which was captured by the allocation factor. One of our estimation guidelines was to only account for the food outflow of those quantities reserved for human consumption (Gustavsson *et al*., 2013). As the staple crop in the country, rice production is primarily utilized as food in the country. This form of commodity use is, in turn, reflected in our findings.

On the other hand, the allocation factor we adopted for corn demonstrates the stark difference between the grains' losses. Our data indicate that only about a fifth of the commodity is used for human consumption (JBIC Institute, 2002). Even in the corn mass flows model, we found most of its quantities in the non-food utilization elements. All these imply that our FLW estimates only reflect a segment of the commodity supply chains. Consequently, it is possible that accounting for the commodity outflow in the non-food supply chains might result in greater levels of FLW.

The critical loss point for corn is agricultural production, where we estimated 117,880 MT of corn loss. When we consider the sub-stages, corn harvesting accounts for the highest loss level (21.85%), followed by shelling (16.15%). The causes of harvesting loss were unharvested corn and spillage, while that of threshing loss were incomplete shelling, accidental mixing of corn grains with the cobs, and low quality of threshing machine used (UNIDO, 2012).

In contrast with our results, Castro (2003) reports that drying contributes the highest share of corn losses (37%), followed by storage (24%) and shelling (21%). This divergence does not necessarily negate our estimates. The study where we derived the weight percentages of loss/waste for corn reported that two typhoons affected the harvest period during the cropping season of recall. Since weather patterns heavily influence agriculture, rainfall could play a vital role in the discrepancy between the critical points of this study and that of Castro (2003). The weather disturbances caused the continued deterioration of the kernels, which was evident in its discoloration, fungal growth, and mechanical damage (UNIDO, 2012).

The other critical loss point of corn is the distribution stage, where we estimated 63,040 MT worth of the commodity was lost/wasted. UNIDO (2012) reports that torn sacks (26,877 MT) and pest infestation during storage (36,165 MT) were the reasons for the FLW generation.

The reaching effect of natural calamities can be seen in the drying activity (i.e., processing and packaging stage) of corn. Although this stage is not as critical as the other two, drying contributes a 12.39% (27,410 MT) share of the total estimated corn losses. During the typhoons, the submersion of the kernels prolonged the drying time, which was aggravated by the preferred method of sun-drying, and resulted in discoloration (UNIDO, 2012).

3.3 Banana

Compared to grains, fruits are more perishable commodity items, which could be the primary reason why bananas generated the highest percentage share of losses among the three crops. Our estimated banana FLW of 20.05% might be the highest in our analysis, but literature indicates that bananas losses in the Philippines can range from 4-60% (Serrano, 2006).

As previously mentioned, the distribution stage is the critical loss point for the FSC of bananas. Two actors were operating at this stage; the consolidator and the wholesaler contributed to 12.53% (124,530 MT) and 17.24% (134,640 MT) of total FLW, respectively. These levels are due to their continued handling, sorting, and transport of bananas, as Calica *et al.* (2018) reported.

For highly perishable items such as fruits, time and distance are essential in the generation of loss/waste. The Philippines is an archipelagic country composed of over 7,000 islands, making the transportation of highly perishable goods challenging. Our study source for the banana loss/waste weight percentages reported that the bananas were transported in an uncontrolled environment for 12 hours from the area of production to the location of the trader/wholesaler (Calica *et al.*, 2018). In a country with high temperature and relative humidity, the common lack of temperature control during the succeeding stages of harvesting is conducive to the deterioration of the produce (Mopera, 2016).

Another critical loss point for bananas is agricultural production. During the production stage, there is a practice called dehanding. It is an activity where each hand of a banana bunch is removed. However, farmers disregard the bottom two hands because they are small and immature, thus, deemed unmarketable by consolidators (Calica *et al.*, 2018). This practice resulted in 29.08% or 342,346 MT of banana losses, the highest in the production stage.

Although dehanding is a common farm activity after harvesting banana bunches, the act of discarding the bottom two hands is a consequence of a market standard. Compared to the other underlying causes previously mentioned, FLW due to market standards is not the result of a decision or limitation of a single actor. It also involves actors that are beyond the stage where the standards are realized as loss/waste. In dehanding bananas, farmers follow the directive of the middlemen, who then follow the demand preferences set by consumers. To counter the FLW resulting from market standards, changes in attitude, commodity use, or expectation would involve all three actors.

Our estimate for banana waste was 16.87% of the total FLW or 67,321 MT at the consumption stage. According to Esguerra *et al.* (2017), the primary reason for fruit wastage was the consumers' forgetfulness to eat the item. Since fruits inherently have a short shelf-life, extensive delay in consumption can highly contribute to wastage. The onset of decay can happen immediately after, or even before, the point of purchase.

4. CONCLUSIONS

We used the methodology designed by Gustavsson *et al.* (2013) to estimate FLW generation in the Philippines. Our study provides the first estimates of the problem, covering the entire extent of the FSC in the country. Given the novelty of this analysis in the country, we suggest further research and relevant policy design in addressing the problem.

First, our study highlights the need for a standard and well-established FLW definition at the level of the

FSC. According to the literature, institutional objectives and motivation guide the characterization of 'loss' and 'waste' (FAO, 2014; Chaboud and Daviron, 2017; Cattaneo, *et al*., 2021). Consequently, this stipulation gives entities some flexibility in establishing their interpretation of the terms. However, they should also consider the definitional implications on FLW measurement and policy creation. For example, by adopting the definition of Gustavsson *et al.* (2011) in our study, which only considers edible quantities intended for human consumption, our estimates only represent a fragment of the agrifood sector. We recognize that the omission of the non-food supply chains underestimates the magnitudes and restricts the achievement of a comprehensive FLW reduction policy.

Concerning policy design, the agreed-upon terminology should also not contradict the reduction efforts at the country level. In our estimations, we considered the rejected banana hands at the dehanding activity as losses in the banana FSC. Although farmers repurpose the rejected bananas as feed (Calica *et al.,* 2018), the definition of Gustavsson *et al.* (2011) prescribes the inclusion of such quantities to the FLW estimations. This situation implies that although the bananas were recovered and reused by the farmers, they will remain 'lost' because of the confines of the established definition. From a policy perspective, this might render specific reduction efforts ineffective because of the measurement guidelines followed. Therefore, the resulting estimates might undermine the accuracy of tracking policy successes or failures.

Another limitation in quantifying the extent of FLW in the Philippines is the lack of an accounting standard covering all stages of the FSC. The absence of a consistently used methodology is an obstacle in accurately identifying the critical loss points and, by extension, the achievements or failures in minimizing the problem. The country-relevant actors can refer to the growing body of literature on this topic. Of recent note is the micro-level survey developed and tested by Delgado *et al.* (2021), which covered the current gaps in the measurement of FLW—quantity and quality losses and pre-harvest losses. Moreover, their methodology also allows for results to be comparable across countries and provides a granular understanding of the problem at the producer, middleman, and processor level. Food waste, however, was not covered in their newly proposed method because of its distinct data collection and measurement requirements from food loss (Delgado *et al.,* 2021). This specificity suggests that the micro-level analysis of FLW requires a mixture of methods to capture the total amounts of food outflow from the entire chain.

Compounding the issue on the creation of an accounting standard is the intricacy of the FSC. From the illustration of Gustavsson *et al.* (2013), the FSC may seem simple. Further, our estimations may reflect a singular FSC for a commodity. In reality, one commodity has numerous supply chains, and each varies in extent and number of actors. While it is improbable to determine every existing chain in the food system, there is a need to understand the trend of commodity flow through each stage and sub-stage and analyze the FLW-influencing actions and decisions. This situation implies the need to balance the benefits and limitations of micro and macro-level analysis from a policymaking perspective.

Another consideration in analyzing FLW is detecting the drivers of its generation. Although identifying the extent of the problem is a vital part of FLW information, determining the accompanying causes of the estimated figures can lead to a deeper understanding of the issue. By extension, the availability of this information will contribute to the accurate design of FLW reduction policies.

Furthermore, the lack of relevant data that constrained our paper also challenges evidence-based policymaking. Our FLW estimates strongly depend on the availability of reliable loss/waste weight percentages and conversion and allocation factors, among other information. The Philippines shares with other countries the lack of these critical statistics from official sources, compromising the quality of the estimates. We extend the same concern with some of the elements needed in the mass flows model.

Unfortunately, the repercussions of national data deficiencies are not isolated within a country. It is also consequential on a global scale. As targets in the SDGs, the Global Food Loss Index and the Food Waste Index, which were developed and under the respective management of FAO and UNEP, rely on country-level statistics (Fabi & English, 2019). The indices will reflect the growth or decline of FLW over time. As such, Fabi *et al.* (2021) stress the need for comparable and reliable national data in light of coordinating reduction policies and worldwide monitoring of the problem. The authors also called the international community to formulate a standard definition and metadata to create synergies in data collection and policy actions (Fabi *et al*., 2021).

Comparing our results and those from other studies shows the need to consider the conditions under which FLW estimates were calculated. Depending on the time of data collection or the relevant cropping season of recall, the presence of extreme weather events is likely to affect FLW levels. In alignment with our findings, the study of Delgado *et al.* (2021) also reported that producers of selected staple crops in Ecuador, Peru, Guatemala, Honduras, and China all indicated the lack of rainfall or other weather conditions as one of their causes of loss.

Our comparison of results also suggests that social and cultural aspects reveal a deeper insight into the causes of FLW generation. While capacities and knowledge are important in current practices, embedded social and cultural structures also affect the actions and decisions of FSC actors. Soma *et al.* (2021) also highlight this point and express that practices, particularly that of farmers, are not solely based on rational decisions. Instead, it results from the interplay of their physical assets, competencies, and viewpoints (Soma *et al.*, 2021). Thus, analyzing and incorporating the underlying causes of FLW in reduction policy design may be more beneficial to the relevant FSC actors.

Our evidence suggests that all stages of the FSC contribute to the generation of FLW in the Philippines. However, the critical loss points and the determinant factors are commodity-specific. Therefore, effective policies aimed at reducing FLW should be calibrated at the specific FSC stages. Our analysis shows that the following shortcomings pose the most significant challenge in preserving the food quantities in the FSC: technological limitations, farming practices, and market standards in the rice, corn, and banana chains, respectively. It follows that efforts targeted at these issues may significantly reduce the problem. In line with the notion set by FAO (2019), addressing these constraints may be highly consequential in improving the FLW levels in the country.

Our study also highlights a fundamental mechanism of the FSC—it is a relay of the commodity from one stage to another. In other words, the FLW incurred in the later stages may be affected by the activities performed or omitted in the prior ones (Gustavsson *et al.*, 2011). Although the critical loss points have the greatest potential in reducing FLW levels, this peculiarity also demonstrates the importance of addressing the bottlenecks in other FSC points. This consideration suggests a supply chain system approach for the containment of FLW and not a fragmented policy intervention focused on the single stages (Luo *et al.*, 2021).

In the pursuit to reduce FLW, the FAO (2019) also pointed out the possibility of establishing acceptable levels of loss/waste, which would warrant further research effort. This suggestion is rooted in the diminishing marginal returns of investments and the potential negative trade-offs with other sustainability aspects (FAO, 2019; Chaboud & Daviron, 2017). Although the FAO (2019) acknowledges the difficulty of setting such a threshold, its identification can guide policy coherence, which is important in allocating limited mitigation resources, particularly in developing countries such as the Philippines.

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