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Quantifying Food Losses in the Beans Value Chain in Rwanda: Analysis and Results from a Baseline Survey

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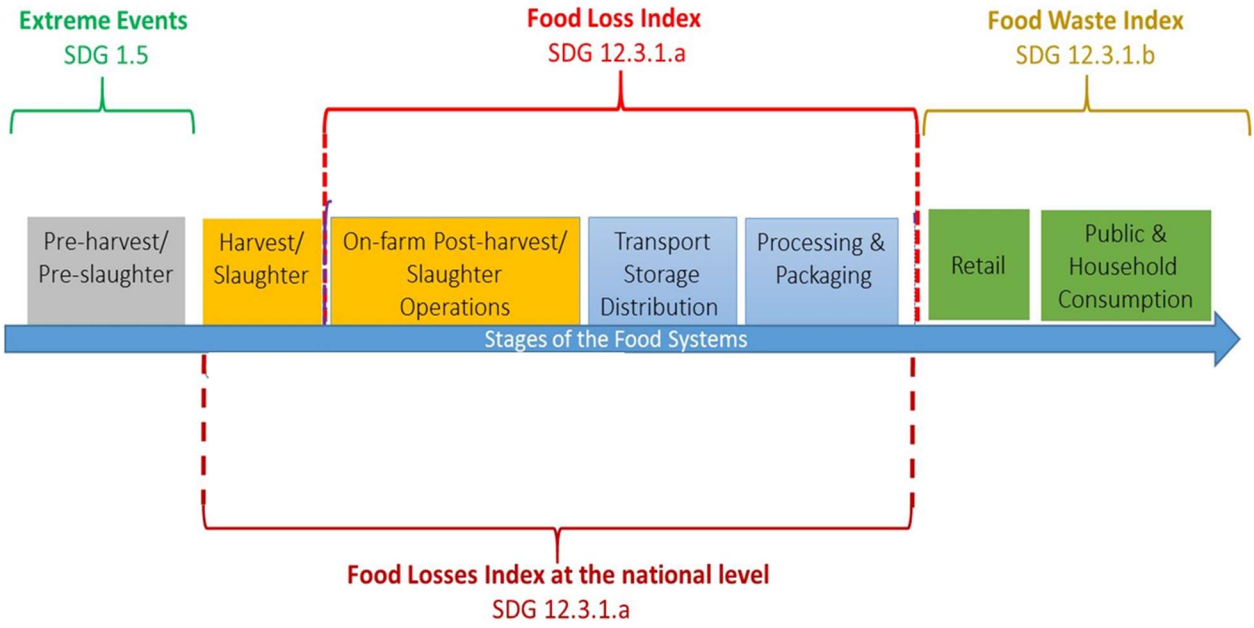
BACKGROUND[1]

At the global level, awareness about the significance of food loss and waste has grown significantly over the past decade. The international community has taken the matter to hand as part of the 2030 Agenda for Sustainable Development and has committed to "halve the per capita global food waste at the retail and consumer level and reduce food losses along production and supply chains, including post-harvest losses" by 2030 (SDG target 12.3).

In 2011, FAO released estimates indicating that up to 30 percent of annual global food production for human consumption may be lost or wasted. While these estimates have been widely cited in policy debates and academic papers, the estimates have been heavily criticized. The State of Food and Agriculture 2019 (SOFA 2019) highlights an improved methodology and partial update of these estimates, based on the development of the Food Loss Index (Figure 1) and ongoing FAO and other research concerning food loss and waste. FAO's most recent estimation indicates that globally 13.2 percent of food is lost between harvest and retail (SDG Data Portal). Delgado et al., 2021, have developed a methodology consistent with FAO's SOFA 2019 to measure food loss and identify where it occurs along the value chain. This information is key to better inform the design of targeted policies and effective programs for reducing food loss.

Figure 1: Food Loss Index



Source: SOFA (2019).

Food loss has caught the attention of both researchers and policymakers for several reasons. First, growing populations and changing diets associated with growing incomes are increasing the pressure on the world's available land, constituting a serious threat to food security, especially in developing countries. Second, food loss entails unnecessary greenhouse gas emissions and excessive use of scarce nonland

[1] The *International Food Policy Research Institute* (IFPRI) partners with the *World Food Program* (WFP) in this study that is part of the *Strengthening Food Systems to Promote Increased Value Chain Employment Opportunities for Youth* project funded by the *Mastercard Foundation*. The project aims to provide tested options for creating innovative, digitally savvy livelihood opportunities for youth, especially young women, while reducing post-harvest losses (PHL) across agrifood systems in Africa.

resources, putting pressure on the environment. Third, the loss of marketable food reduces producers' income and increases consumers' expenses, likely having larger impacts on disadvantaged segments of the population (Torero et al., 2018).

There is substantial evidence of food losses occurring throughout all value chains, but little is known about the magnitude of these losses. Consequently, there needs to be more evidence-based research in understanding the magnitude of these losses and their socioeconomic impact, especially on youth[2] and women. So far, the main known drivers of food losses along the value chain are lack of financial means, low managerial knowledge, and technical limitations in handling production at the post-harvest stage (FAO, 2021).

Rwanda is not an exception to this global problem. The country's population is expected to double over the next 30 years, which will likely increase food insecurity concerns (World Bank, 2020). Additional challenges will arise from climate change impacts. Based on the Notre Dame global adaptation initiative index, which measures vulnerability to climate change adaptation, Rwanda is ranked 112th internationally in 2021 out of 182 countries. This implies that while progress is being made in responding effectively to climate change, the adaptation requirements, and the urgency to take action are even more significant (ND-GAIN, 2023). Food losses and waste in the country are about 40 percent of its food supply (World Bank, 2020). In this context, the government of Rwanda is working to achieve an economic transformation as stipulated in the National Strategy for Transformation 2017-2024 (NST 1). According to the plan, the Rwandan government imparts the role of investing in post-harvest handling infrastructure as an important intervention that will help lead to economic transformation through increased productivity and modernization of the agriculture sector. The Ministry of Agriculture's (MINAGRI) Strategic Plan for Agriculture Transformation 2018-2024 (PSTA-4) further emphasizes the importance of addressing food losses, its link to the performance of the agricultural sector and the growth of farmers' income and identifies the main drivers of these losses to be the lack of adequate post-harvest handling, technical capacity, and facilities. In its theory of change, PSTA-4 recognizes the importance of markets in driving the transformation of the agricultural sector from subsistence farming to a market-led agricultural sector. However, achieving inclusive markets is still an elusive goal hampered by high levels of post-harvest losses as they impede farmers from supplying enough and appropriate raw materials to agribusinesses and/or processors. Addressing the infrastructure and knowledge gap concerning post-harvest losses is crucial because the provision of data for select key value chains and the strengthening and development of post-harvest technology and infrastructure is vital for MINAGRI to help achieve its third outcome of improving productivity and inclusiveness of agricultural market systems and increasing value addition and competitiveness of diversified agricultural commodities, for domestic, regional, and international markets (MINAGRI 2018).

In PSTA 4 and in its new National Agriculture Policy (NAP) (2018), MINAGRI intends to strengthen post-harvest management through capacity development (skills and knowledge) and development of appropriate technology and post-harvest infrastructure (MINAGRI, 2018). As the fourth policy pillar of the NAP promotes improving productivity and strengthening inclusive markets and off-farm opportunities, strengthening market linkages throughout the value chain is important, and measuring post-harvest losses along key value chains, including beans, is crucial. Bucagu et al., 2018 estimated beans losses in the northern and western provinces were 13.5 percent at harvest and post-harvest handling and 23.3 percent at storage in 2018.

[2] The African Union defines young people as individuals between the ages of 15 and 35 years.

In its fourth strategic plan (PSTA 4), Rwanda's Ministry of Agriculture identifies six main value chains among which are beans. In Rwanda, beans are a primary staple, and the country has consumption rate of 164 grams/day per capita (Onyago, 2021). Almost all rural farm households engage in cultivating beans, making it one of the most produced crops in the country (Larochelle et al., 2013). In Rwanda, beans are more commonly grown by rural women, and they sometimes use it as an alternative cash crop. Beans have also traditionally been regarded as a woman's crop (IMC Worldwide, 2020) Considering their growth characteristics, beans planted in Rwanda either grow as bush beans or climbing beans and according to a recent commercialization survey, 52 percent of Rwandan households planted bush beans, and 42 percent planted climbing beans in 2022. This bean production was mainly used for consumption, with only 27 percent of climbing bean-producing households and 35 percent of the bush bean-planting households selling their 10 percent and 13 percent of their total production in the market. The production (28 percent of the total climbing bean production and 35 percent of the total bush bean production) that was not consumed nor sold was either used as animal feed, saved as seeds, stored, lost postharvest and/or used as in-kind payment (Warner et al., 2023).

Figure 2 shows that the production and yield of dry beans in Rwanda over the last decade. In 2021, beans were found to be cultivated by the highest proportion of Rwandan households, with 81 percent of the households having grown beans in Season A of 2021 (NISR 2021).[3] However, in 2020 due to a drought, the production decreased compared to other years. Although beans are essential in Rwanda (Figure 2), handling the harvested beans is yet to be optimized.

Figure 2: Dry Beans Production and Yields in Rwanda

Data Source: FAOSTAT (2023).

Understanding and closing the gap on food losses, especially in developing countries, has become an important topic, and there has been tremendous progress made recently in measuring food losses and where these losses occur along the value chain (Delgado et al., 2021). This report aims to study the nature of the losses and characterize them by utilizing novel and precise measurements. Specifically, it seeks to: 1. Identify the production stages and processes during which losses occur; 2. Determine the

[3] There are two crop annual cropping seasons in Rwanda. Cropping Season A relies on the major rains in September-January months while the Season B relies on the rains in February-June.

extent of losses along the value chain and, 3. Pinpoint the locations where these losses happen. This research project is part of the collaboration between the Mastercard Foundation, World Food Program, and International Food Policy Research Institute in the *Strengthening Food Systems to Promote Increased Value Chain Employment Opportunities for Youth* project. *These* efforts are geared towards strengthening the food system by empowering rural farmers and fostering increased value-chain employment, with a particular emphasis on benefiting youth and young women. This goal aligns with the Young Africa Works initiative[4] and the Regional Food Systems Initiative.[5] As the agricultural sector in Rwanda in 2021 employs 66.4 percent (NISR, 2022) of the total working population, it is crucial to understand the underlying causes leading to food losses and inefficiencies across food value chains. This research work is especially important in Rwanda as it aligns with the NST 1, PSTA 4, NAP, and Gender and Youth Mainstreaming Strategy.[6] Gender and youth of producers represent two distinctive yet interlinked dimensions of agricultural communities. In the ever-evolving landscape of agriculture, understanding the roles, challenges, and contributions of both groups is essential for fostering sustainable and inclusive agricultural practices. Gender considerations illuminate the unique experiences and responsibilities of female producers within farming households, while youth producers, with their energy and potential, hold the key to the sector's future.

METHODOLOGY

Methodology for this research is based on Delgado et al., 2021. Clear knowledge regarding the magnitude of food loss and waste is critical to better address the problem (Lipinski et al., 2013). While uniform estimation methods that provide consistent loss figures are necessary, more is needed to identify the underlying causes of and potential solutions to food loss, outline priorities for action, and monitor specific progress on loss reduction targets.

Drawing on literature and economic theory, we implement three alternative methodologies in addition to the traditionally used aggregate self-reported loss measures method. All three methodologies can measure losses at different stages of the value chain and can be applied across crops and regions. The methodologies are based on information collected through representative surveys of producers, aggregators, and processors between the production and processing stages. These surveys allow the characterization of inputs, harvesting, storage, handling, and processing practices for each agent and estimate the production's quantities, quality, and values as it travels along the value chain.

All methodologies estimate the total amount of food lost (quantity degradation, estimated in quantity and value) and the product that, albeit not completely lost, is affected by quality deterioration (estimated in quantity and value). At the producer level, we estimate losses from harvest to post-harvest sale, with the reference period being the last cropping season (Season A 2023). For the aggregators and the processors, we estimate losses from purchase to sale during a defined time (depending on the crop), but from the same season of the producer survey. Due to the heterogeneity of the crop transformation processes at later stages in the value chain, only the aggregate self-reported measurement method is used at the processor level.

[4] Mastercard Foundation project: https://mastercardfdn.org/wp-content/uploads/2021/06/Young-Africa-Works-Strategy.pdf

[5] Joint World Food Programme and Mastercard Foundation Initiative

[6] The Gender and Youth Mainstreaming Strategy is Rwanda's Ministry of Agriculture Strategy that aims to ensure that women, men, and youth benefit equally from policy action, programs, and activities and that inequality is not perpetuated.

As part of this methodology, survey tools were developed to be able to collect representative and detailed information among different agents in the value chains (i.e., farmers, aggregators, wholesale buyers, and processors) for wheat, maize, beans, teff, potatoes, tomatoes, yam, and groundnuts in different countries (4 of them in Africa). The survey instruments designed allow identifying quantity and quality losses and where they occur in the value chain.

This methodology is consistent with the basic elements in the available literature on measuring food losses. It includes a disaggregated description of the stages and processes in which losses occur.

The attribute method is an improvement over existing methodologies by (a) properly sampling; (b) accounting for losses from the pre-harvest stage through product distribution and postharvest; and (c) by including both losses in quantity and quality deterioration as part of the measurement of loss. Because of this project's objectives pointed above, we will use the attributes methodology based on Delgado et al. (2021), outlined below.

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.[7] 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 damaged or affected by inferior attributes, both after production and after post-harvest.[8] Aggregators evaluate their product from the previous month at both purchase and sale. The producer and the aggregators declare how much their respective buyers' produce is of inferior quality and punish them for these product attributes by paying them a lower price. The price punishment information for each product attribute is used to estimate the loss in value.

At the producer level, the quantity and quality degradation in weight ($WeightLoss_P$) and in value ($ValueLoss_P$) for producer p are given by equations 1 and 2, respectively:

$$WeightLoss_p = \left(Q_{Prod,p} - Q_{PH,p} \right) + \sum_{j=1}^{J} a_{j,p} * Q_{PH,p} \quad (1)$$

$$ValueLoss_p = \left(V_{Prod,p} - V_{PH,p} \right) + \sum_{j=1}^{J} \overline{Pa}_{j,p} * Q_{PH,p} \quad (2)$$

where $Q_{Prod,p}$ and $Q_{PH,p}$ are respectively the quantity of all produce after production and after post-harvest for producer p, and $a_{j,p}$ is the share of product affected by damage attribute j. $V_{PH,p}$ and $V_{Prod,p}$ are the value of all produce after production and after post-harvest, respectively. The multiplication of $Q_{Prod,p}$ and $Q_{PH,p}$ by the ideal price $\bar{P}_{ideal}$. $\bar{P}_{ideal}$, is the average sale price for an ideal product. $\overline{Pa}_{j,p}$, is the average price punishment for an inferior product attribute at sale. This is obtained from the

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

[8] In other words, a producer defines the percentage of its produce that is respectively rotten, swollen, too pale, deformed, has an acid smell, broken, too small, has an uncommon texture, etc.

difference in the typical market price of the product at the producer level and the lower producer-level price given a specific damage. While the first terms of eq. 1 and 2 provide us with the total quantity or value lost (quantity degradation) between production and post-harvest, the second terms provide us with the quantity affected by a loss (quality degradation).

At the aggregator level, the quantity and quality degradation in weight ($WeightLoss_m$) and in value ($ValueLoss_m$) for aggregators m are given by eq. 3 and 4, respectively:

$$WeightLoss_m = WeightTotLoss_m + \sum_{aj=1}^{J} (Q_{Purchase,aj,m} - Q_{Sale,aj,m}) \quad (3)$$

$$ValueLoss_m = ValueTotLoss_m + \sum_{aj=1}^{J} (V_{Purchase,aj,m} - V_{Sale,aj,m}) \quad (4)$$

where $WeightTotLost_m$ and $ValueTotLost_m$ are the weight and value of the quantity that was totally lost. $Q_{Purchase,aj,m}$ and $Q_{Sale,aj,m}$ are the quantities in each attribute sold and purchased with a certain damage attribute by aggregator *m*. $V_{Purchase,aj,m}$ and $V_{Sale,aj,m}$ are the values at sales and purchase that are lost due to a damage attribute and are obtained by multiplying the previous quantities ($Q_{Purchase,aj,m}$ and $Q_{Sale,aj,m}$) by an average price punishment at purchase and sale, obtained from the difference in the typical aggregators-level market price of the product and the lower price given a specific damage.

SURVEY IMPLEMENTATION

Sampling framework

The study survey was conducted in May-June 2023 by IFPRI in collaboration with Laterite-Rwanda, closely coordinated with the Agriculture Value Chain Management and Trade Directorate of MINAGRI-RWANDA. The survey was applied to the beans value chain.

The survey employed a stratified random sampling method with proportional allocation of beans producers of Season A 2023[9] per selected district. Additionally, chain-referral sampling was used to select aggregators and processors.

The survey covered all five provinces of Rwanda, including farming communities surrounding the City of Kigali. Within each province, data were collected from the two districts with the highest percentage of bean-producing households (Table 1), which is determined based on bean production data from the Seasonal Agriculture Survey 2022, Season A, and households that produced beans from Agricultural Household Survey 2020. These data sources were published by the National Institute of Statistics of Rwanda (NISR). Notably, these districts (except for those in Kigali city) align with districts where WFP is

[9] There are two annual cropping seasons in Rwanda. Cropping Season A relies on the major rains in September-January months while the Season B relies on the rains in February-June

implementing interventions to reduce post-harvest losses in the context of the multi-country project described in the background section.[10]

Table 1: Total beans production by district during 2022 Season A cropping season

Provinces	District	Beans-producing households %	# of HHs producing beans (,000)	Ranking (by % producing households
Kigali city	Kicukiro	88.4	15	1
	Gasabo	84.1	46	2
	Nyarugenge	83.6	19	3
Southern province	Nyaruguru	98.1	67	1
	Gisagara	97.4	90	2
	Huye	95.8	71	3
	Ruhango	95.2	75	4
	Nyanza	94.1	82	5
	Kamonyi	92.7	84	6
	Nyamagabe	89.8	83	7
	Muhanga	88.9	70	8
Western province	Karongi	92.8	72	1
	Rusizi	92.7	82	2
	Ngororero	83.3	86	3
	Nyamasheke	81.9	92	4
	Nyabihu	77.9	65	5
	Rubavu	76.6	53	6
	Rutsiro	72.4	72	7
Northern province	Gicumbi	94.8	96	1
	Gakenke	94.7	85	2
	Rulindo	92.8	81	3
	Burera	90.2	80	4
	Musanze	77.1	88	5
Eastern province	Ngoma	93.6	83	1
	Bugesera	92.4	82	2
	Kirehe	92.2	84	3
	Rwamagana	91.6	73	4
	Kayonza	88.8	83	5
	Gatsibo	85.5	100	6

[10] WFP interventions in the beans value chain in Rwanda works through the Farm to Market Alliance (FtMA). The FtMA provides trainings to farmers on how to access predictable markets, farming inputs, and affordable finance. More specifically, FtMA provides training to beans farmers on access to post-harvest handling and storage (PHHS) technologies. The PHHS trainings aim at helping farmers reduce their post-harvest losses, increase their marketable surplus, improve, and maintain their grain quality and fulfil their forward delivery contracts. The trainings are structured along six sections. Namely: Controlling crop quality; managing harvest; drying and protecting crops; threshing and cleaning crops; sorting and grading; and storing crops.

	Nyagatare	73.7	109	7
	Total	**88.6**	**2,268**	

Source: NISR, AHS 2020.**Source:** NISR, AHS 2020.

Note: In green, those districts selected for data collection

Within each of these selected districts, the number of villages visited was proportional to the relative number of households engaged in bean farming. This was calculated using the data from NISR, AHS (2020) by taking the ratio of the total number of bean producers within the district (numerator) to the total number of bean producers for the districts selected in all the provinces (denominator).

Utilizing the list provided by WFP, we initially identified 15 villages where interventions would be implemented (referred to as "treatment" villages) based on their proximity and connectivity to the main road and the local market. Subsequently, we randomly selected an additional 45 villages (termed "control" villages), resulting in three control villages for each treatment village across all provinces. This distribution will allow us to technically through matching method identify an average control that is the closest as possible in observable characteristics to each treatment.

Producers' sample size

The target sample size for bean producers across all five provinces was established at 700 based on budget limitations. Sampling with replacement was utilized to accommodate potential non-responses or unavailability during the survey.

Our goal was to survey 14 producers in each treatment village, totaling 210 producers from treatment villages, and 11 producers in each control village, reaching a total of 495 producers from control villages. These targets within each village ensured that we would reach the overall goal of 700 respondents. Furthermore, the uneven distribution between treatment and control villages ensured that one-third of the final sample would be located in treatment villages.

Table 2 provides an overview of the distribution of the villages sampled at the district level, differentiating between treatments and control villages[11] while the design and final producer sample distribution at village level is shown in Annex 1.1.

Table 2: Sample Village Distribution by District

Province	District	# (%) of Households Farming Beans in 2020 (2022A)	Proportion of all households that produced beans in 2020 in the 10 districts	Number of Treatment Villages Selected	Number of Control Villages to Be Selected	Total Number of Villages Selected
Kigali	**Kicukiro**	15,000 (88.4%)	0.021	0	2	2
	Gasabo	46,000 (84.1%)	0.064	0	4	4
Southern	**Nyaruguru**	67,000 (98.1%)	0.093	4	3	7
	Gisagara	90,000 (97.4%)	0.125	4	3	7

[11] To accommodate for the uneven distribution of treatment villages across districts; Kicukiro and Nyaruguru count an effective number of sampled villages slightly higher than the number of households farming beans in those areas. In contrast, Gisagara, Rusizi, and Bugesera count an effective number of sampled villages marginally lower.

Western	**Karongi**	72,000 (92.8%)	0.100	1	5	6
	Rusizi	82,000 (92.7%)	0.114	0	6	6
Northern	**Gicumbi**	96,000 (94.8%)	0.134	3	5	8
	Gakenke	85,000 (94.7%)	0.118	0	7	7
Eastern	**Ngoma**	83,000 (93.6%)	0.116	2	5	7
	Bugesera	82,000 (92.4%)	0.114	1	5	6
	Total	718,000	1	15	45	60

Source: Authors' elaboration based on Laterite (2023) and NISR, AHS (2020)

Sampling strategy

To randomly select control villages, we employed a list of pre-selected treatment-matching villages compiled at the sector level, considering their accessibility to assure that the treatments and controls have the same level of access to markets, including travel times to the nearest primary or secondary road and the nearest city. To achieve this, we applied a methodology that relies on raster analysis, involving several steps (Maruyama et al., 2018). First, global geographic data on water, roads, railroads, topography, and natural barriers, publicly available from DIVA-GIS and GIS land cover type data from NASA and the USGS are projected for Rwanda. Second, the country is split into equal sized grids of 100 m^2 and travel time estimates are determined that account for the unique 100 m^2 topologies. Third, optimized travel time from the centroid of the village to the closest primary or secondary road and closest city was estimated.

The optimization process established the fastest travel time from the village's centroid to either the road or city. To select control villages, we used the calculated average travel time to the road for all WFP villages as a threshold. Consequently, all villages in the list were at a distance equal to or below the average travel time of WFP villages, ensuring that all selected villages were highly accessible and provided suitable controls for the WFP intervention villages in terms of proximity to the main road.

In each district, we randomly determined the number of villages to be selected, which corresponded to the proportion of households producing beans in 2020, as specified in Table 2.

For each potential control village within each sector, we assigned a random number generated using the statistical software Stata. These villages were then arranged in ascending order based on their assigned random numbers, and the required number of control villages, as specified in Table 2 at the district level, were retained. The distribution of villages between sectors in each district was equal. For example, if a district required the selection of four villages and had two listed sectors, two villages were chosen per sector.[12] If a selected village did not have a sufficient number of bean producers to survey, we adjusted the random order within that sector to identify a replacement village.[13]

Study sample.

In this study, we focused on three distinct populations, each playing a different role within the beans value chain:

[12] In case it resulted into decimal numbers, we randomly selected the sector that will count one more village than the other sectors in the district.

[13] In practice, we only had one replacement case where the first two villages did not have enough bean farmers according to the village leader.

- **Producers of beans (F=700):** Specifically, we targeted producers who had recently sold all or part of their harvest.
- **Aggregators of beans (A=200):** These are individuals that have purchased beans from producers with the intention of selling them at markets beyond the village-level.
- **Processors of beans (P=100):** This group encompasses those who process the beans sold by producers surveyed and aggregated by the aggregators surveyed.

To identify the producers, we conducted a listing exercise within the selected villages for data collection, extending invitation to farmers who met the specified qualification outlined below. The aggregators and processors were identified through a snowballing approach, beginning with the aggregators identified in the producer survey, and supplemented by a list of processors provided by local partners.

Producer selection

Within each village, we included farmers who had both produced and sold part of their bean harvest during 2023 Season A cropping season.

Eligibility criteria for bean producers were determined during the field preparation phase. At this stage, producers were selected according to following eligibility criteria:

1. Producers who cultivated beans during 2023 Season A cropping season (from September 2022 to February 2023).

2. Producers who typically farm beans individually specifically for the harvest season of interest.

3. Producers who primarily produce for sale, with a significant portion of their harvest sold.

Aggregators and processors selection

Using information provided by the producers, the survey team employed chain referral sampling techniques to identify and select bean buyers, intermediaries, aggregators, and processors for interviews. Due to limited available information regarding the location and number of active individuals involved in these related activities, this approach was essential in choosing suitable respondents.[14]

Under this method, the initial respondents—typically one or two—were identified and interviewed. They were then asked to assist the enumerators by introducing them to aggregators and processors within the network. These follow-up interviews were conducted through phone calls.

The aggregators and processors sample distribution are shown in Annex 1.2.

DATA

We have developed three comprehensive survey tools covering various aspects of the beans value chain. These survey tools serve the purpose of quantifying food loss throughout the value chain before consumption, using standardized approaches that can be compared across different commodities and

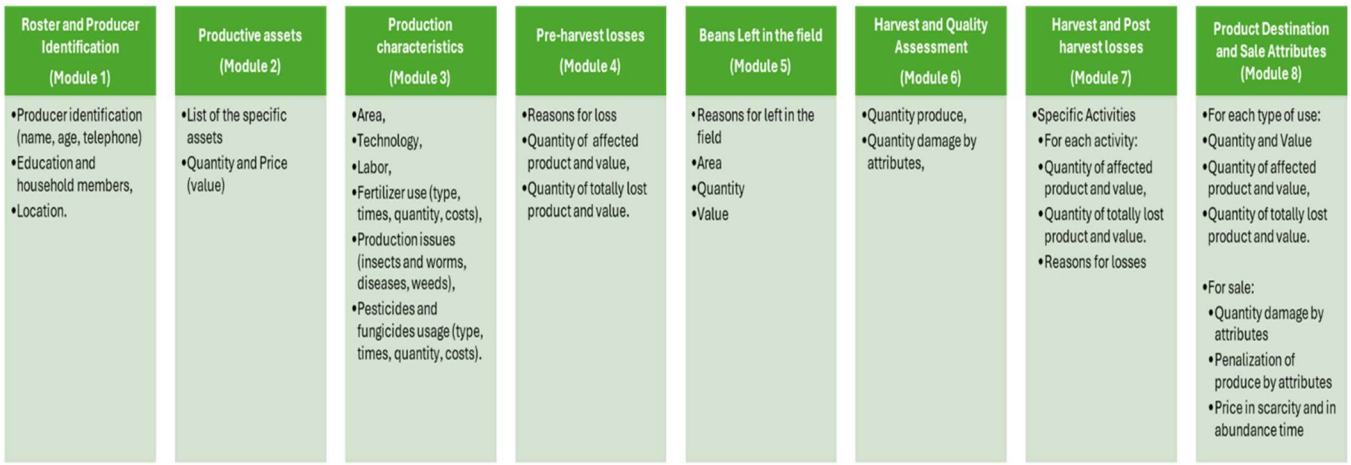
[14] Despite considerable efforts invested in listing a sufficiently large number of aggregators and processors, we encountered challenges in reaching the targeted sample size. These challenges included offline phones, respondents not answering, and lack of consent, among other factors. The sampling approach highlighted the absence of direct links between producers and processors in Rwanda.

regions. Additionally, they allow us to characterize the nature of food loss, particularly identifying the production stages and specific processes during which losses occur.

The producer survey questionnaire consists of several modules, each serving a unique purpose:

Roster and Producer Identification (Module 1): This module is used to identify and register the producer. This provides information on age, sex, education, as well as the geographical location.
Asset and Production Characteristics (Modules 2 and 3): These modules collect data related to assets and production characteristics.
Pre-harvest Losses (Module 4): This module focuses on measuring the quantity of beans lost during the pre-harvest stage and identifying the sources of these losses. It also measures the value losses due to qualitative degradation, serving to gauge also farmers' incentive to improve the quantity and quality of production.
Beans Left in the Field (Module 5): Here, we record the quantity of good quality beans that remain in the field after harvest and the reasons.
Harvest and Quality Assessment (Module 6): This module captures data on the total production harvested, as well as the qualities, attributes, and prices associated with the harvest.
Harvest and post-harvest Losses (Module 7): This module involves gathering information on the quantity affected by quality degradation[15] and the total quantity lost[16] during post-harvest activities, such as winnowing, threshing, grading, transporting, and packaging. It also identifies post-harvest handling and storage techniques that contribute to food losses and measures the value losses due to qualitative degradation and quantitative losses, gauging farmers. incentives to improve the quantity and quality of production.
Product Destination and Sale Attributes (Module 8): This module tracks the product's destination, whether it is for consumption, sale, donation, or other purposes. It also records attributes related to the quantity intended for sale.

Figure 3: The producer survey questionnaire modules.



Source: Authors' elaboration based on Delgado et al., 2021

[15] Affected product: Product that lowers quality but can still be used.

[16] Totally lost: Product that is completely lost and cannot be used.

The aggregators' survey questionnaire comprises four distinct modules:

Roster and Aggregator Identification (Module 1): This module is designed to identify and register the aggregator. This provides information on age, sex, education, as well as the geographical location.
Purchase Details (Module 2): In this module, we gather information about the quantity, quality, value and attributes of the total product purchased during a specified period.
Post-Harvest Losses (Module 3): Module 3 focuses on quantifying the quantity and value of affected product and the total loss and value incurred during post-harvest processing activities for beans.
Sales Information (Module 4): The fourth module pertains to the quantity, quality, attributes and value of the total product sold within a defined period, tailored to the context of Rwanda.

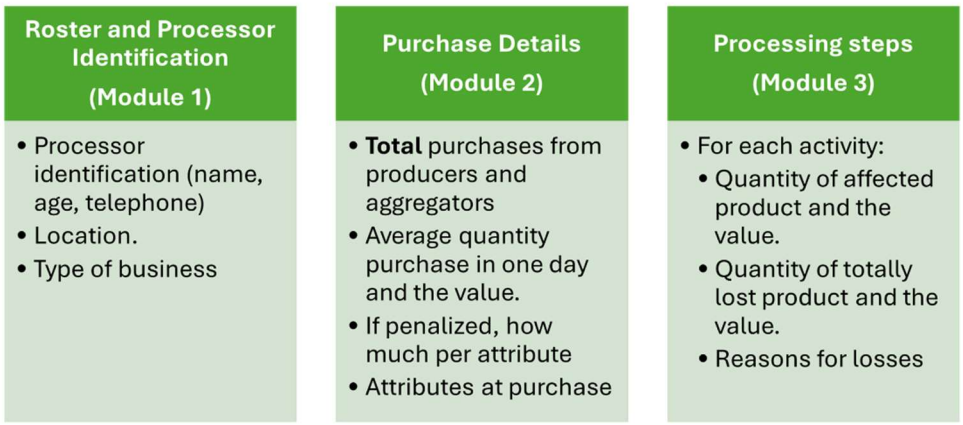
Figure 4: The aggregator survey questionnaire modules.

Source: Authors' elaboration based on Delgado et al. (2021).

The processor survey consists of three key modules:

Roster and Processor Identification (Module 1): This initial module is used for identifying and registering the processor.
Purchase Details (Module 2): Module 2 collects information regarding the quantity, quality, and attributes of the total product purchased during a specified period, which may vary depending on the country's context.
Processing Steps (Module 3): The third module inquiries about the steps involved in transforming the acquired product into the final product intended for consumption, including the losses and their value at each step.

Figure 5: The processor survey questionnaire modules.



Source: Authors' elaboration based on Delgado et al. (2021).

In the attributes section of each survey, producers, aggregators, and processors are asked to evaluate the physical or chemical characteristics of the crops. These characteristics, specific to beans in Rwanda, were identified in collaboration with value chain actors and beans experts, including the East African Standards.[17] In our surveys, crop damage is determined by factors such as texture, size, moisture, and the presence of fungus or insects, among others. We further validate this through expert consultations and the price punishment that each of these types of crop damage entails in the different market locations.

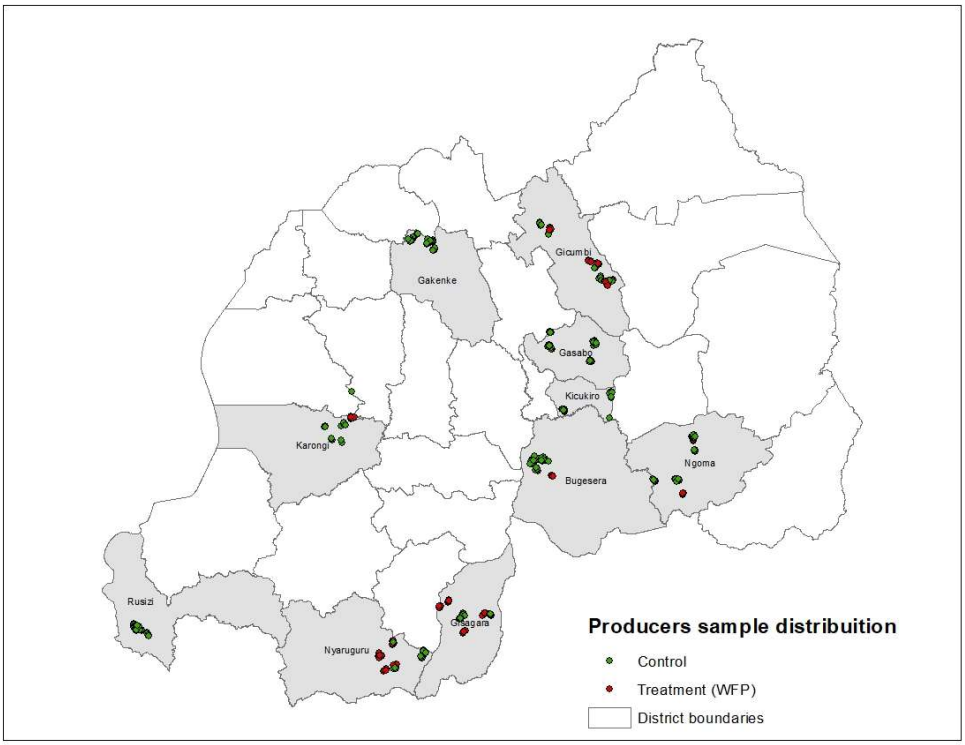
[17] The East African Standards (EAS) serve as a cornerstone in aligning quality requirements for products and services across the East African Community (EAC). Established to address trade barriers within the Community, these standards are meticulously developed under the guidance of the East African Standards Committee (EASC). The EASC, comprised of representatives from National Standards Bodies, public and private sector entities, fosters a collaborative and inclusive approach.

RESULTS

Summary statistics

Beans value chain

Figure 6: Distribution of producers' surveys by group.



Source: Authors' illustration

Producers' characteristics

The data collected from the producer survey offers valuable insights into the food losses of beans in Rwanda. Table 4 shows the characteristics of 2023 Season A beans producers where the majority of beans production is carried out by male producers, accounting for 59.2 percent of the surveyed population, with an average age of 48.4 years across the sample. Treatment villages exhibit a higher percentage of male producers at 65.5 percent compared to 56.5 percent in control villages, while the average age of producers in both groups varies by just a year.

The surveyed producers reside in households with an average size of 5.4 members, an average that increased to 6.2 members per household in the Western province.

The primary occupation for a vast majority of the surveyed producers (98.5 percent) is farming, with a notable exception in Kigali city, where 8.5 percent of producers are engaged in alternative occupations such as petty trade, employment in private companies, education, and preaching. Educational attainment varies, with 84.5 percent of surveyed producers having only primary school education or no formal education. In contrast, 5.2 percent have completed secondary school education, with the Northern and

Western provinces reporting the highest secondary school completion rates at 6.9 percent and 6.8 percent, respectively.

During the 2023 Season A cropping season, producers surveyed cultivated an average of 0.36 hectares of land for bean production. The average quantity of beans produced per producer was 193.1 kilograms, with notable variations in production between provinces. For instance, producers in Kigali city, who on average cultivated 0.46 hectares (ha), achieved the highest average production at 249.5 kg, while producers in the Eastern province, who cultivated an average of 0.41 ha, reported the lowest average production at 166.5 kg. The average yield reported is 910.5 kg/ha; with the highest yields located in the Northern province (1248.4 kg/ha) and the Eastern province with the lowest yields (567.1 kg/ha). This is also comparable to the national yield average of 708.4 kg/ha in 2021 (FAOSTAT, 2023). Improved seeds were used by only 4.1 percent of the surveyed producers, with the Northern province having the lowest adoption rate at 2.9 percent. Interestingly, 79.5 percent of producers in the Northern province reported planting climbing beans while those in the Eastern province predominantly opted for bush beans (88.3 percent). This preference may be influenced by the topography of the respective provinces, with the Northern province being mountainous and the Eastern province relatively flat.

Soil preparation was a common practice among all surveyed producers, with 99.7 percent manually preparing their soil. While 95.5 percent applied fertilizer at least once, the percentage dropped for two and three fertilizer applications. Foliar fertilizer application use was minimal at 0.3 percent and irrigation practices remained low, with only 1.0 percent of producers reporting irrigation.

In the post-harvest phase, 85.7 percent of the producers prepared their storage sites[18], but only 56.4 percent cleaned them. Control villages displayed a higher rate of storage cleaning (61.7 percent) compared to treatment villages (43.8 percent). Most producers (98 percent) stored their production for an average of 2.5-months, primarily at their dwellings (99.7 percent). Approximately 12.1 percent of producers employed modern storage methods[19], with PICS bags being the most popular (90.1 percent).

Most of the produced beans did not reach the market, as producers sold only 32.5 percent of their harvested beans on average. This highlights the limited marketable surplus and the substantial household consumption needs, especially given the importance of beans in the Rwandan diet. By province, differences were observed, with producers in Kigali having the lowest average of sold production (23.8 percent) and the Western province having the highest average of sold production (39.1 percent). Producers primarily sold their beans to aggregators (56.1 percent). For the entire survey, the proportion of beans sold to stores and consumers was approximately equal (23.3 percent). However, practices varied with Kigali producers favoring direct sales to consumers (38.5 percent), while those in the Southern province primarily sold to stores (34.5 percent) after aggregators.

Annex 1.3 presents the statistical tests (t-tests) to assess the similarities of the producers residing in treatment villages from those living in control villages. The analysis revealed that there were a few characteristics that were statistically significant at the 1 percent, 5 percent, and 10 percent statistical levels. Among the socioeconomic characteristics, treatment villages had a higher percentage of male producers than control villages, with a 5 percent level statistically significant difference of 0.08 percentage points. Treatment village producers, with 18.2 percent, had a higher rate of uneducated producers than control villages (11.2 percent) and this difference was statistically significant at the 5 percent level. While the occupation of producers from treatment villages was farming, a few of the producers from control village

[18] Storage site preparation could include cleaning the storage site, fumigation, storage material (like sacks), etc.

[19] Modern storage method includes PICS bags, supergrain bags, barns, plastic and metal silos.

had other primary occupations. This difference in primary occupation was as well significant at the 5 percent statistical level.

Only three characteristics within the production variables stood out as statistically significant: the number of different applied inputs, membership in agricultural cooperatives, and the hiring of labor. A higher percentage of producers from treatment villages were members of agricultural cooperatives than those from control villages. This difference was statistically significant at the 1 percent level. While producers from control villages applied more different inputs than those from treatment villages. This difference was statistically significant at the 5 percent level. A higher percentage of producers from control villages used hired labor than producers from treatment villages, this difference in use of hired labor was significant at the 1 percent statistical level.

Within post-harvest activities, there were as well a few significant differences between the treatment and control village producers. Producers in the control villages practiced a higher number of post-harvest activities and the difference was significant at the 1 percent statistical level. A greater percentage of control village producers cleaned and prepared the storage site more than treatment village producers, both the differences in these two activities between treatment and control villages were significant at the 1 percent statistical level. A greater share of producers from control villages practiced the activity of storing and the difference of storing was statistically significant at the 1 percent level.

Only two activities regarding the sales of production were significantly different. The percentage of producers from treatment villages who sold their production was less than the share of producers from control villages who sold their production. This difference was significant at the 5 percent statistical level. The sale of produce directly to consumers was as well statistically significant at the 1 percent level, with a higher share of control village producers selling to consumers than treatment village producers.

Box 1: Gender and age.

Table 3 provides a comprehensive analysis of producer characteristics, categorized by gender and age. Among the surveyed producers, a mere 14.6 percent fall under the category of youth producers. Within this subgroup, the gender distribution is almost balanced, with males being slightly higher than females at 55.0 percent. The average age for the young producers stands at 31.7 years, while female youth producers have an average age of 31.3 years.

A mere 4.2 percent of the overall producer population possess an upper secondary education. However, when dissecting the data by age groups, a notable increase in the percentage is observed. Specifically, 17 percent of youth producers and 13.3 percent of female youth producers have completed high school education. Intriguingly, all the producers with education beyond the secondary level belong to the mature age group (over 35 years). Households headed by mature producers exhibit a larger average household size, comprising 5.4 members, in contrast to youth producers' households with an average of 4.4 members.

Table 3: Producer Characteristics Categorized by Gender and Age

Variable name			All (N=686)		Youth Producers (35 and below) (N=100)		Female Producers (N=280)		Youth Female Producers (N=45)	
			mean	sd	mean	sd	mean	sd	mean	sd
Socio-economic characteristics	Gender (male)		59.2%	0.5	55.0%	0.5	0.0%	0.0	0.0%	0.0
	Age (years)		48.4	12.0	31.7	3.0	47.8	12.3	31.3	3.2
	Education	No education	13.3%	0.3	8.0%	0.3	15.4%	0.4	8.9%	0.3
		Primary	71.3%	0.5	63.0%	0.5	72.5%	0.4	57.8%	0.5
		Lower secondary	10.2%	0.3	12.0%	0.3	8.2%	0.3	20.0%	0.4
		Upper secondary	4.2%	0.2	17.0%	0.4	3.2%	0.2	13.3%	0.3
		> Secondary	1.0%	0.1	0.0%	0.0	0.7%	0.1	0%	0.0
	Household size		5.4	2.1	4.4	1.4	5.0	2.1	4.6	1.4
	Main occupation	Farming	98.5%	0.1	97.0%	0.2	99.3%	0.1	95.6%	0.2
		Petty Trade	0.4%	0.1	3.0%	0.2	0.7%	0.1	4.4%	0.2
		Education related	0.6%	0.1	0.0%	0.0	0.0%	0.0	0.0%	0.0
		Religious related	0.3%	0.1	0.0%	0.0	0.0%	0.0	0.0%	0.0
		Private sector	0.1%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.0
	Experience in cultivating beans (years)		20.6	12.8	7.6	4.2	21.9	12.8	7.5	3.9
Production	Quantity produced last harvest (Kg)		193.1	226.5	164.8	194.8	157.2	220.8	131.5	122.9
	Area cultivated (in hectares)		0.36	0.37	0.30	0.37	0.34	0.36	0.28	0.22
	Yield		910.5	898.3	856.7	858.4	836.2	911.2	695.3	762.3
	Improved seeds (dummy)		4.1%	0.2	4.0%	0.2	3.2%	0.2	0.0%	0.0
	Climbing beans (dummy)		45.2%	0.5	45.8%	0.5	41.2%	0.5	43.2%	0.5
	Number of different inputs applied		1.5	0.8	1.7	0.8	1.5	0.8	1.6	1.0
	activities		0.0	0.2	0.1	0.2	0.0	0.1	0.1	0.3
	Soil preparation	Manual	99.7%	0.1	100.0%	0.0	100.0%	0.0	100.0%	0.0
		Draught animals	0.3%	0.1	0.00%	0.0	0.0%	0.0	0.0%	0.0
		Mechanical	0.1%	0.0	0.0%	0.0	0.0%	0.0	0.00%	0.0
	Fertilizer Application	Once	95.5%	0.2	95.0%	0.2	95.0%	0.2	88.9%	0.3
		Twice	24.2%	0.4	32.0%	0.5	24.3%	0.4	35.6%	0.5
		Three times	0.4%	0.1	1.0%	0.1	1.1%	0.1	2.2%	0.1
	Foliar Application		0.3%	0.1	0.0%	0.0	0.4%	0.1	0.00%	0.0
	Irrigation		1.0%	0.1	2.0%	0.1	0.4%	0.1	2.2%	0.1
	Number of mechanic production activities		0	0	0	0	0	0	0	0
	Agricultural cooperative membership		20.1%	0.4	11.8%	0.3	15.9%	0.4	8.1%	0.3
	Hired labor		86.6%	0.3	96.0%	0.2	86.4%	0.3	100.0%	0.0
Post-harvest	Nb of post-harvest activities		6.8	0.6	6.8	0.4	6.8	0.7	6.8	0.4
	Post-harvest activity - cleaning storage		56.4%	0.5	58.0%	0.5	56.4%	0.5	57.8%	0.5
	Post-harvest activity - preparing storage site		85.7%	0.4	79.0%	0.4	83.2%	0.4	84.4%	0.4
	Storage (dummy)		98.0%	0.1	98.0%	0.1	97.5%	0.2	97.8%	0.1
	Storage time (in days)		72.0	83.3	71.5	38.7	65.7	38.5	71.2	37.2
	Storage location	House (bag)	99.7%	0.1	100.0%	0.0	99.2%	0.1	100.0%	0.0
	Storage type	Modern	12.1%	0.3	9.2%	0.3	9.2%	0.3	4.5%	0.2
		PICS bags	90.1%	0.3	88.9%	0.3	96.0%	0.2	100.0%	0.0
		Barns at home	1.2%	0.1	11.1%	0.3	0.0%	0.0	0.0%	0.0
	Type of modern storage containers	Metallic silos	3.7%	0.2	0.0%	0.0	0.0%	0.0	0.0%	0.0
		Plastic silos	3.7%	0.2	0.0%	0.0	0.0%	0.0	0.0%	0.0
		Supergrain bag	1.2%	0.1	0.0%	0.0	4.0%	0.2	0.0%	0.0
Sales	Percentage of harvest sold		32.5%	0.2	37.5%	0.3	30.0%	0.2	35.8%	0.3
	Type of buyer the farmer sells to	Middlemen	56.1%	0.5	56.9%	0.5	55.6%	0.5	58.6%	0.5
		Processor	1.0%	0.1	1.5%	0.1	1.2%	0.1	3.4%	0.2
		Store	23.3%	0.4	23.1%	0.4	19.9%	0.4	10.3%	0.3
		Consumer	23.3%	0.4	21.5%	0.4	26.3%	0.4	27.6%	0.5
	Nb of transactions to sell last harvest		1.7	8.4	1.3	0.7	1.3	0.9	1.3	0.9

Source: Authors' calculation using PHL baseline survey (2023).

Continue Box 2: Gender and age

Female-led households have a smaller average size, with 5 members, compared to their male counterparts, who have an average of 5.4 members. Notably, youth female producers report a slightly higher average household size of 4.6 members compared to the overall youth producer group's average of 4.4 members.

While the total sample reveals a relatively low percentage of producers engaged in occupations others than farming (1.5 percent), female youth producers stand out with the highest percentage (4.4 percent) engaged in alternative primary occupations, primarily as petty traders.

Concerning agricultural production, there is little variation in the size of cultivated land across different age and gender groups, with most land averaging between 0.28-0.34 hectares. However, significant differences emerge when assessing average bean production. On average, producers yield 193.1 kg of beans, whereas females producers achieve an average of only 157.2 kg. Among age groups, youth producers report a lower average bean production of 164.8 kg, with young female producers recording the lowest average production at 131.5 kg. The yield of these groups is lower than the average of the total sample. The youth group reported an average of 856.7 kg/ha, while the yield for female and youth female producers were 836.2 kg/ha and 695.3 kg/ha respectively the lowest yields of all groups.

Compared to the young male and older female producers, female youth producers exhibit the lowest percentage of single-time fertilizer application (88.9 percent). Interestingly, this group of young female producers reports higher percentages for two- and three-times fertilizer applications, at 35.6 percent and 2.2 percent, respectively. Young female producers also show a relatively higher percentage (2.2 percent) of soil irrigation than both young male and older female producers, although this remains a minority practice. Youth producer groups, particularly all female young producers, have the highest percentage of producers hiring external labor, surpassing other demographics groups. However, surveyed youth producers appear less likely to belong to agricultural cooperatives (11.8 percent) compared to the overall sample and the female subgroup.

Notably, a higher percentage of male producers employ modern storage and use a variety of modern storage methods, whereas female producers who store modernly (9.2 percent), predominantly use PICS bags (96 percent). All young female producers utilizing modern storage (4.5 percent) exclusively rely on PICS bags. Youth producers (9.2 percent) primarily opt for two types of modern storage, PICS bags (88.9 percent) and home barns (11.1 percent). In contrast, mature producers (12.5 percent) have more diversified modern storage options, including metallic store (4.2 percent), plastic silos (4.2 percent), and supergrain bags (1.4 percent).

Aggregators characteristics

Table 5 provides a comprehensive overview of the characteristics of the aggregators included in our survey, shedding light on the key players in the bean trade sector. Notably, the majority of individuals involved in this trade are male, comprising 74 percent of the total aggregator population in our survey. This is a significantly higher proportion of males compared to producers in the same sector.

On average, aggregators are approximately 42 years old, making them notably younger than the average age of producers. Despite their relatively younger age, aggregators bring an average of 9 years of experience to the table, reflecting their seasoned expertise in aggregating beans. Intriguingly, only a negligible percentage operate formally, underscoring the prevalent informality within this sector.

Regarding their role in the bean supply chain, the majority of aggregators (84 percent) primarily source their beans directly from producers. Additionally, a substantial proportion of aggregators (36 percent) acquire beans directly from other aggregators[20], demonstrating a certain degree of collaboration and interdependence within the bean trade network.

In terms of sales, a significant portion of aggregators (77 percent) engage in direct sales to final consumers, while 55 percent sell beans to other intermediaries, reflecting the complexity of the market. A smaller percentage of aggregators (18 percent) sell beans to processors, and 13 to retailers showcasing the various avenues through which beans are distributed.

Post-harvest processes also play a crucial role, with a considerable number of aggregators involved in various stages of bean handling. Notably, 39% are involved in drying beans, 31% in cleaning and packaging, and 91% in storage. Additionally, 22% are engaged in transportation, collectively contributing to the quality and accessibility of beans in the market.

Further analysis of demographic subgroups unveils additional insights. In the youth and female groups, aggregators predominantly source beans directly from producers and engage in similar sales and post-harvest processes as observed across the entire sample, underlining the uniformity of operations within these subgroups.

Processors characteristics

Table 6 serves as a valuable resource for understanding the characteristics of processors in our survey. All the individuals in the sample cook the beans as part of the process intended for sale to the public, either in restaurants or markets. Forty-three percent are male, indicating a balanced gender distribution within this segment of the industry. The average age of processors stands at 39 years, suggesting a workforce with considerable experience. However, on average, processors bring only three years of experience to the bean processing industry, hinting at a mix of both seasoned professionals and newcomers.

One striking observation pertains to the formalities of operations. Merely 21% of processors operate as formal businesses, shedding light on the prevalent informality within the bean processing sector. This suggests that a significant portion of businesses may lack extensive legal structures or formal registration.

[20] These variables are not mutually exclusive, as aggregators can purchase from more than one type of seller.

When it comes to sourcing raw materials, processors overwhelmingly rely on aggregators, with 99.9% preferring this method. This underscores the pivotal role intermediaries play in facilitating the flow of beans to processing facilities. Conversely, only a negligible proportion (0.1%) purchase beans directly from producers, emphasizing the preference for the convenience and efficiency offered by aggregator networks.

Further analysis of demographic subgroups unveils additional insights. In the youth group, comprising processors with an average age of 27 years and two years of experience, 40% operate formal businesses. Similarly, on the female processors group, averaging 40 years of age with four years of experience, exhibit a lower rate of formal business registration at 13%.

Despite these variations, both subgroups predominantly rely on aggregators for bean procurement, with minor differences observed in direct sourcing from producers. Overall, the data underscores the complex dynamics of the bean supply chain and highlights the pivotal role of aggregators as key intermediaries in the process.

Table 4: Producer characteristics

	Variable name		All (N=686) mean	sd	Treatment (N=203) mean	sd	Control (N=483) mean	sd	Kigali City (N=59)* mean	sd	Southern (N=175) mean	sd	Western (N=133) mean	sd	Northern (N=173) mean	sd	Eastern (N=146) mean	sd
Socio-economic characteristics	Gender (male)		59.2%	0.5	65.5%	0.5	56.5%	0.5	64.4%	0.5	57.1%	0.5	55.6%	0.5	66.5%	0.5	54.1%	0.5
	Age (years)		48.4	12.0	49.0	12.2	48.2	11.8	49.7	11.4	49.5	12.1	47.0	11.8	48.3	12.0	48.1	12.1
	Education[1]	No education	13.3%	0.3	18.2%	0.4	11.2%	0.3	13.6%	0.3	16.0%	0.4	9.8%	0.3	12.1%	0.3	14.4%	0.4
		Primary	71.3%	0.5	67.0%	0.5	73.1%	0.4	67.8%	0.5	70.9%	0.5	78.9%	0.4	69.9%	0.5	67.8%	0.5
		Lower secondary	10.2%	0.3	10.3%	0.3	10.1%	0.3	13.6%	0.3	10.3%	0.3	4.5%	0.2	11.0%	0.3	13.0%	0.3
		Upper secondary	4.2%	0.2	3.0%	0.2	4.8%	0.2	5.1%	0.2	2.3%	0.1	6.8%	0.3	4.0%	0.2	4.1%	0.2
		> Secondary	1.0%	0.1	1.5%	0.1	0.8%	0.1	0%	0.0	0.6%	0.1	0.0%	0.0	2.9%	0.2	0.7%	0.1
	Household size		5.4	2.1	5.3	2.0	5.4	2.1	5.8	1.8	5.1	2.0	6.2	2.4	5.2	2.0	5.1	2.0
	Main occupation	Farming	98.5%	0.1	100%	0.0	97.9%	0.1	91.5%	0.3	100%	0.0	99.2%	0.1	97.7%	0.2	100%	0.0
		Petty Trade	0.4%	0.1	0%	0.0	0.6%	0.1	3.4%	0.2	0%	0.0	0.8%	0.1	0%	0.0	0%	0.0
		Education related	0.6%	0.1	0%	0.0	0.8%	0.1	1.7%	0.1	0%	0.0	0%	0.0	1.7%	0.1	0%	0.0
		Religious related	0.3%	0.1	0%	0.0	0.4%	0.1	1.7%	0.1	0%	0.0	0%	0.0	0.6%	0.1	0%	0.0
		Private sector	0.1%	0.0	0%	0.0	0.2%	0.0	1.7%	0.1	0%	0.0	0%	0.0	0%	0.0	0%	0.0
	Experience in cultivating beans (years)		20.6	12.8	20.7	12.8	20.6	12.8	19.5	12.3	22.1	12.7	20.2	12.8	21.0	12.9	19.4	13.0
Production	Quantity produced last harvest (Kg)		193.1	226.5	193.5	203.2	192.9	235.9	249.5	509.7	188.1	161.5	180.7	131.1	210.8	190.7	166.5	214.3
	Area cultivated (in hectares)		0.36	0.37	0.36	0.41	0.36	0.35	0.46	0.47	0.39	0.37	0.36	0.35	0.26	0.27	0.41	0.41
	Yield (kg/ha)		910.5	898.3	980.9	954.5	880.9	873.0	757.9	859.6	912.5	980.3	912.8	862.9	1248.5	951.1	567.1	590.2
	Improved seeds (dummy)		4.1%	0.2	4.9%	0.2	3.7%	0.2	3.4%	0.2	5.1%	0.2	4.5%	0.2	2.9%	0.2	4.1%	0.2
	Climbing beans (dummy)		45.2%	0.5	41.8%	0.5	46.5%	0.5	25.4%	0.4	41.2%	0.5	53.5%	0.5	77.5%	0.4	11.7%	0.3
	Number of different inputs applied		1.5	0.8	1.4	0.7	1.6	0.8	1.3	0.8	1.5	0.7	1.7	0.9	1.7	0.8	1.3	0.8
	Number of different field maintenance activities		0.0	0.2	0.0	0.2	0.0	0.2	0.0	0.1	0.0	0.2	0.0	0.2	0.0	0.2	0.0	0.1
	Soil preparation	Manual	99.7%	0.1	100%	0.0	99.6%	0.1	98.3%	0.1	99.4%	0.1	100%	0.0	100%	0.0	100%	0.0
		Draught animals	0.3%	0.1	0%	0.1	0.2%	0.0	1.7%	0.1	0.00%	0.0	1%	0.1	0%	0.0	0%	0.0
		Mechanical	0.1%	0.0	0%	0.0	0.2%	0.0	0.00%	0.0	0.6%	0.1	0%	0.0	0%	0.0	0%	0.0
	Fertilizer Application	Once	95.5%	0.2	97%	0.2	95.0%	0.2	89.83%	0.3	100.0%	0.0	96%	0.2	100%	0.0	86%	0.3
		Twice	24.2%	0.4	20%	0.4	25.9%	0.4	18.64%	0.4	18.3%	0.4	32%	0.5	26%	0.4	24%	0.4
		Three times	0.4%	0.1	0%	0.0	0.6%	0.1	0.00%	0.0	0.0%	0.0	2%	0.1	1%	0.1	0%	0.0
	Foliar Application		0.3%	0.1	0%	0.0	0.4%	0.1	0.00%	0.0	0.0%	0.0	1%	0.1	0.6%	0.1	0%	0.0
	Irrigation		1.0%	0.1	1%	0.1	1.0%	0.1	1.69%	0.1	0.6%	0.1	1%	0.1	1%	0.1	1%	0.1
	Number of mechanic production activities		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Agricultural cooperative membership		20.1%	0.4	32.7%	0.5	15.8%	0.4	21.1%	0.4	37.3%	0.5	7.1%	0.3	17.3%	0.4	19.3%	0.4
	Hired labor		86.6%	0.3	82.8%	0.4	88.2%	0.3	96.6%	0.2	85.7%	0.4	93.2%	0.3	78.0%	0.4	87.7%	0.3
Post-harvest	Nb of post-harvest activities		6.8	0.6	6.7	0.6	6.8	0.6	6.5	0.8	6.7	0.5	6.9	0.4	6.9	0.4	6.7	0.9
	Post-harvest activity - cleaning storage		56.4%	0.5	43.8%	0.5	61.7%	0.5	39.0%	0.5	53.1%	0.5	75.9%	0.4	57.2%	0.5	48.6%	0.5
	Post-harvest activity - preparing storage site		85.7%	0.4	80.3%	0.4	88.0%	0.3	81.4%	0.4	83.4%	0.4	84.2%	0.4	85.0%	0.4	92.5%	0.3
	Storage (dummy)		98.0%	0.1	96.6%	0.2	98.6%	0.1	96.6%	0.2	97.1%	0.2	99.2%	0.1	98.8%	0.1	97.3%	0.2
	Storage time (in days)		72.0	83.3	77.7	142.1	69.6	37.2	85.2	44.9	77.5	152.4	68.8	34.6	75.4	37.0	58.9	32.9
	Storage location	House (bag)	99.7%	0.1	100.0%	0.0	99.6%	0.1	94.4%	0.2	100.0%	0.0	100.0%	0.0	100.0%	0.0	100.0%	0.0
	Storage type	Modern	12.1%	0.3	11.7%	0.3	12.2%	0.3	0.0%	0.0	8.8%	0.3	15.9%	0.4	14.6%	0.4	14.1%	0.3
		PICS bags	90.1%	0.3	87.0%	0.3	91.4%	0.3	0.0%	0.0	80.0%	0.4	95.2%	0.2	88.0%	0.3	95.0%	0.2
		Barns at home	1.2%	0.1	4.3%	0.2	0.0%	0.0	0.0%	0.0	0.0%	0.0	4.8%	0.2	0.0%	0.0	0.0%	0.0
	Type of modern storage containers	Metallic silos	3.7%	0.2	4.3%	0.2	3.4%	0.2	0.0%	0.0	13.3%	0.4	0.0%	0.0	4.0%	0.2	0.0%	0.0
		Plastic silos	3.7%	0.2	4.3%	0.2	3.4%	0.2	0.0%	0.0	6.7%	0.3	0.0%	0.0	4.0%	0.2	5.0%	0.2
		Supergrain bag	1.2%	0.1	0.0%	0.0	1.7%	0.1	0.0%	0.0	0.0%	0.0	0.0%	0.0	4.0%	0.2	0.0%	0.0
Sales	Percentage of harvest sold		32.5%	0.2	28.9%	0.3	34.0%	0.2	23.8%	0.3	27.0%	0.2	39.1%	0.2	35.6%	0.2	33.0%	0.3
	Type of buyer the farmer sells to	Middlemen	56.1%	0.5	60.9%	0.5	54.3%	0.5	50.0%	0.5	66.7%	0.5	47.0%	0.5	54.2%	0.5	58.2%	0.5
		Processor	1.0%	0.1	0.9%	0.1	1.0%	0.1	3.8%	0.2	1.1%	0.1	1.2%	0.1	0.0%	0.0	1.0%	0.1
		Store	23.3%	0.4	25.5%	0.4	22.5%	0.4	3.8%	0.2	34.5%	0.5	31.3%	0.5	20.3%	0.4	15.3%	0.4
		Consumer	23.3%	0.4	15.5%	0.4	26.2%	0.4	38.5%	0.5	6.9%	0.3	22.9%	0.4	28.8%	0.5	27.6%	0.4
	Nb of transactions to sell last harvest		1.7	8.4	2.9	16.1	1.3	0.9	1.8	1.8	3.5	18.1	1.2	0.7	1.3	0.7	1.2	0.6

Source: Authors' calculation using PHL baseline survey (2023).

Table 5: Aggregators characteristics

Variable Name		All (N=139)		Youth Aggregators (35 and below) (N=37)		Female Aggregators (N=36)	
		mean	sd	mean	sd	mean	sd
Gender (male)		74%	0.44	89%	0.315	0%	0
Age (years)		42	10.62	30	4.3	46	10.32
Experience in bussiness (years)		9	8.72	5	3.22	12	10.28
Formal bussiness (dummy)		1%	0.09	0%	0	0%	0
Quantity purchase in the last month of transaction (kg)		4402.8	27091.19	1232.4	1874.75	871	1364.86
Value purchased in the last month of transaction (USD)		3691.3	20414.51	1143.5	1867.32	854.6	1272.16
Type of seller	Producers	84%	0.37	89%	0.32	97%	0.17
	Middlemen	37%	0.48	27%	0.45	39%	0.49
Quantity purchased from different sellers in the last month of transaction(Kg)	Producers	3304.51	19406.11	942.42	1536.18	583.94	886.43
	Middlemen	4483.67	15403.62	1450	2011.63	779.79	824.08
Quantity sold in the last month of transaction (Kg)		4100.19	26843.78	1112.3	1835.87	674.5	898.97
Value sold in the last month of transaction (USD)		4062.55	23678.64	1101	1808.77	736.91	889.41
Price paid for 1 kg of best quality product (USD)	Abundance	0.65	0.17	0.63	0.18	0.72	0.18
	Scarcity	1.12	0.17	1.12	0.18	1.13	0.21
Price received for 1 kg of best quality product (USD)	Abundance	0.71	0.21	0.69	0.21	0.79	0.23
	Scarcity	1.23	0.18	1.2	0.14	1.27	0.21
Type of buyers sold to	Middlemen	55%	0.5	46%	0.51	69%	0.47
	Retailer	13%	0.34	11%	0.32	25%	0.44
	Processor	18%	0.39	8%	0.28	36%	0.49
	Consumer	77%	0.42	70%	0.46	83%	0.38
Post-harvest activities	Drying	39%	0.49	41%	0.5	42%	0.5
	Cleaning and packaging	31%	0.46	30%	0.46	39%	0.49
	Storage	91%	0.28	92%	0.28	94%	0.23
	Transport	22%	0.42	19%	0.4	22%	0.42

Source: Authors' calculation using PHL baseline survey (2023).
Note: The official exchange rate in the year of the survey was 0.0009 USD/ Rw Franc (www.xe.com)

Table 6: Processor characteristics

Variable name		All (N=28)		Youth Processors (35 and below) (N=10)		Female Processors (N=16)	
		mean	sd	mean	sd	mean	sd
Gender (male)		43%	0.5	50%	0.53	0%	0
Age (years)		39	11.27	27	4.88	40	10.67
Experience in business (years)		3	3.24	2	2.2	4	3.54
Formal business (dummy)		21%	0.42	40%	0.52	13%	0.34
Proportion of kg of bean purchased from	Producers	0.10%	0.5	4.40%	0.5	14.90%	0.5
	Aggregators	99.90%	0.5	95.60%	0.5	85.10%	0.5
Quantity of sellers		4	5	4	5.6	4	5.1
Quantity purchased in the last month of transaction (kg)		10878.4	56662.7	157.8	110.8	136.3	86.8
Value purchased in the last month of transaction (USD)		10087.9	52261.2	200.2	146.4	166.8	115.8

Source: Authors' calculation using PHL baseline survey (2023).
Note: The official exchange rate in the year of the survey was 0.0009 USD/ Rw Franc (www.xe.com).

ESTIMATED FOOD LOSSES

Figure 7a provides an insightful visualization of losses at different stages of the bean value chain, including producers, aggregators, and processors. It is important to note that some observations were excluded from analysis due to missing values[21]. Losses encompass both quantity degradation, where the product completely disappears from the value chain, and quality degradation, where the product is affected by quality deterioration but can still be used for various uses. The losses are presented in both weight and value, allowing for a comprehensive assessment of their economy.

As depicted in Figure 7, losses within the bean value chain average 44.1 percent and 28.5 percent of total volume and value of production, respectively. Notably, losses are consistently highest at the producer level, accounting for an average of 79.6 percent and 68.4 percent of total volume and value of food losses, respectively. At the aggregator level, the losses are 2.7 percent and 3.7 percent of total volume and value of food losses, respectively. Losses by processors constitute 17.6 percent and 27.9 percent of the total value chain in terms of volume and value of beans, respectively.

When assessing losses in terms of value, post-harvest losses have a more significant economic impact, accounting for greater than 58 percent of the total value losses, compared to losses at the pre-harvest stage, which represents 41 percent of the total value losses[22]. This difference in distribution between value and volume losses may be attributed to the increasing value added to beans as they progress along the value chain due to various activities conducted during processing and distribution. This sheds light on the critical areas where interventions to reduce losses can have a substantial economic impact within the bean value chain.

Figures 7b and 7c provide a deeper dive into losses at the producer level by treatment and control villages, presenting them as percentages of the total volume and value of production at various stages of production, including pre-harvest, left in the field, and post-harvest. In terms of volume on average, the data collected reveals that the majority of losses at the producer level occur at the pre-harvest stage (73 percent of total losses), followed by those at the post-harvest stage (26 percent) and then those left in the field (1 percent).[23]

Gender and age.

In terms of producer-level analysis, it was found that females experience a total volume loss of 38.0 percent and a value loss of 21.9 percent. The largest portion of volume losses occurs during the pre-harvest stage, accounting for 71.7 percent of total losses, followed by post-harvest losses at 28.2 percent, with negligible losses left in the field (0.1 percent).

Regarding the youth group, a total volume loss of 35.3 percent and a value loss of 17.5 percent were observed. Similar to females, the majority of volume losses among youths occur pre-harvest, constituting 77 percent of total losses, followed by post-harvest losses at 22 percent, and minimal losses left in the field (1 percent).

[21] From the 700 producers who participate in the survey; 14 producers were excluded.

[22] The value loss is calculated using the quantity of losses.

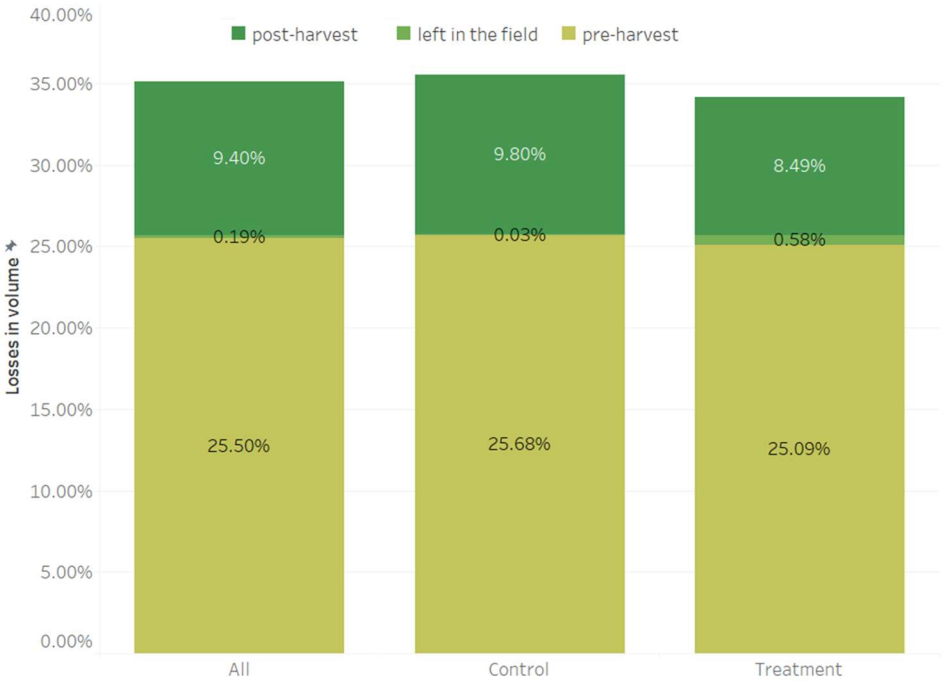
[23] Only five producers reported left in the field.

It is noteworthy that the distribution of losses within both sub-groups (females and youth) mirrors the patterns observed in the overall sample, as well as in both the treatment and control groups.

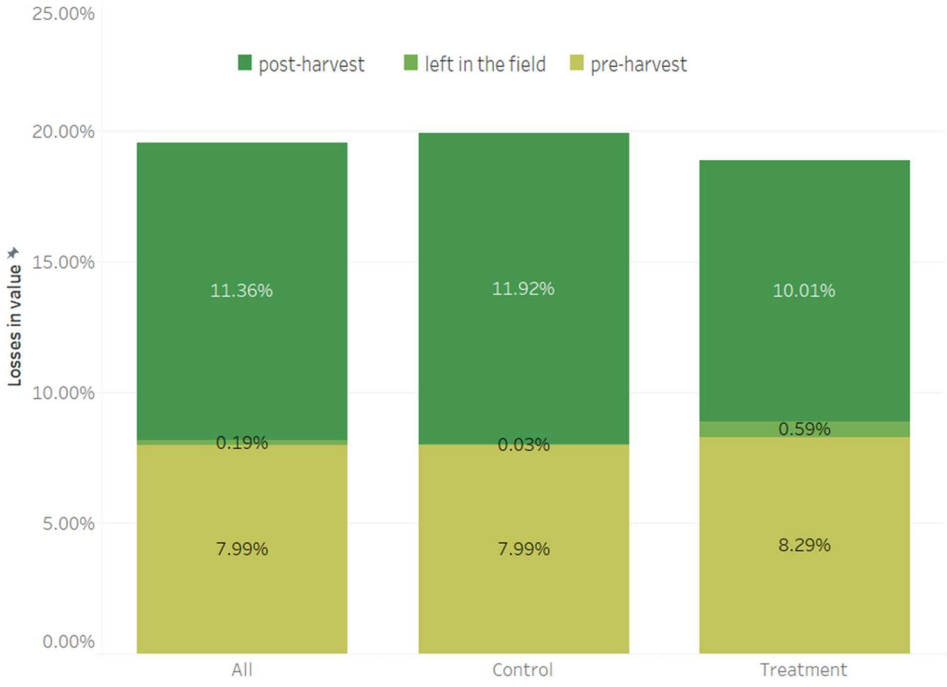
Figure 7: Estimated Food Losses along the Beans Value Chain in Rwanda in 2022- Season A

a) Food Loss in the Beans Value Chain as Percentage of Total Volume (kg) and Value (USD) of Production

b) Food Loss in the Beans Producers as a Percentage of Total Volume (kg) of Production by Treatment Group



c) Food Loss in the Beans Producers as a Percentage of Total Value (USD) of Production by Treatment Group



Source: Authors' calculation using PHL baseline survey (2023).

CAUSES OF FOOD LOSSES

Production Stage

Figure 8 offers insights into the major reasons reported by producers to explain their pre-harvest, left in the field, and post-harvest losses in the bean value chain.

Pre-harvest

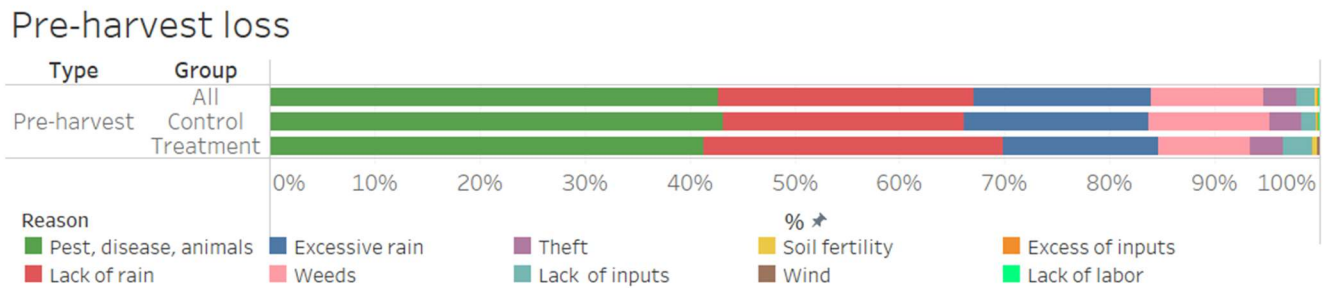
For pre-harvest losses, producers predominantly cited pests and diseases as the primary reasons for their losses. Weather-related problems, such as excessive or insufficient rainfall, were also significant factors contributing to pre-harvest losses. Additionally, weeds were also reported as a noteworthy factor affecting beans loss at pre-harvest.

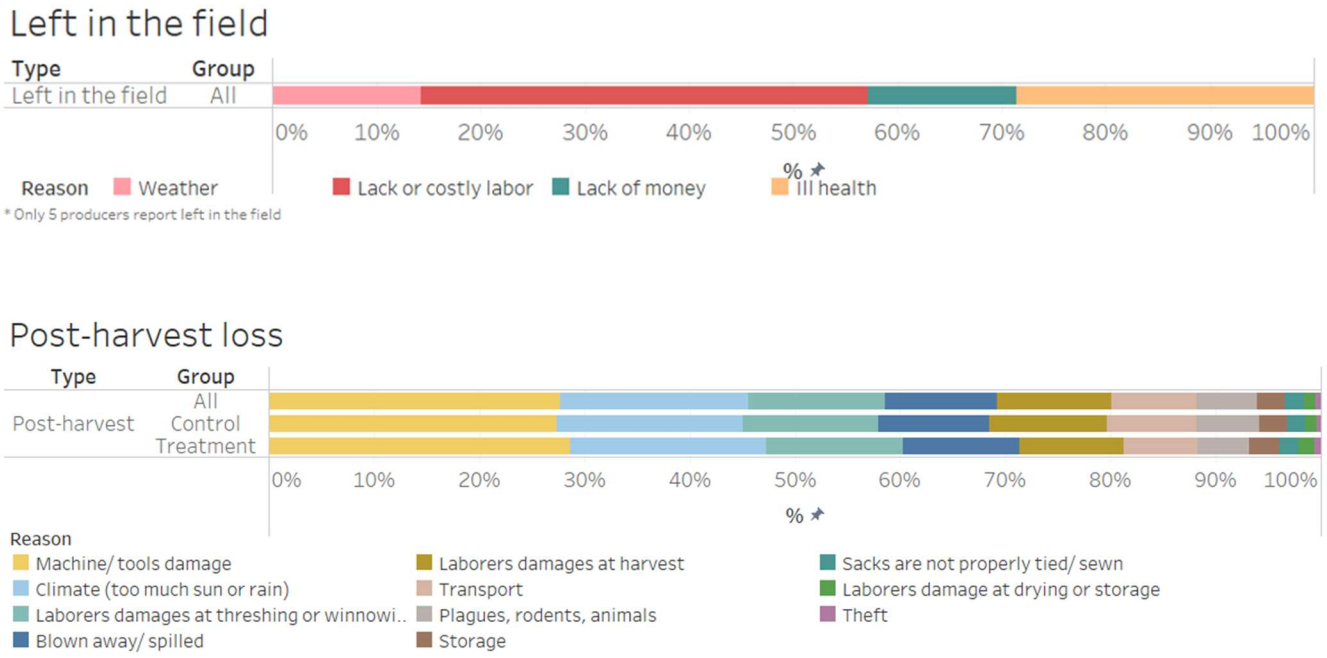
Losses due to pest and diseases

Full sample

Details of the pest-related issues presented in Annex 2.1 show that a substantial proportion of bean producers (74.2 percent) reported encountering pest-related challenges in their cultivation endeavors. These challenges prompted 32.7 percent of producers to deploy a range of pest management approaches, including bio pesticides, chemical insecticides/pesticides, fungicides, and biological insecticides. Notably, the most popular method among these producers was the application of chemical insecticides, with a staggering 92.4 percent of them using pesticide management approaches opting for this strategy. However, despite these efforts, a significant 54.2 percent of all producers still experienced losses attributable to pests. Interestingly, not all pest management strategies proved equally effective. Of those who reported losses due to pests, 35.8 percent had previously applied chemical insecticides, 4 percent had turned to bio pesticides, 2 percent had adopted integrated pest management, 1.7 percent had used fungicides, and 2.9 percent had explored biological insecticides. These findings reveal the diversity of approaches employed and underscore the challenges faced in effectively controlling pest infestations.

Figure 8: Self-Reported Causes of Losses at the production stage of the beans value chain in Rwanda in 2022- Season A





Source: Authors' calculation using PHL baseline survey (2023).

Treatment vs control

When the data is analyzed by treatment and control villages, patterns emerge. Producers from control villages reported a higher percentage (35.4 percent) of managing pest infestations compared to their counterparts from treatment villages (26.1 percent). Moreover, producers from control villages were twice as likely to employ bio pesticides in their pest management strategies compared to those from treatment villages.

Geographical variation

Geographically, Kicukiro district stood out with the lowest share of producers (31.3 percent) reporting losses attributed to pests and diseases. This geographical variation highlights the potential influence of local conditions on pest-related challenges.

Gender and age

Age groups also played a role in pest management preferences, as the youth group reported a higher incidence of pest issues and demonstrated greater proficiency in addressing them. They exhibited a slightly higher preference for biopesticides and integrated pest management. In contrast, the mature group leaned more towards the use of chemical products.

Losses due to weeds

Annex 2.2 provides valuable insights into the prevalence of pre-harvest losses attributed to the presence of weeds in bean cultivation. The findings shed light on the impact of weed infestations and the strategies employed by producers to mitigate these losses.

Full sample

A notable 65.2 percent of the entire sample reported encountering issues with weeds during their bean cultivation. However, the majority of these producers demonstrated effective manual weed control techniques. Surprisingly, only 26.7 percent of the producers reported experiencing losses directly attributable

to weeds. Intriguingly, none of the interviewed producers reported the use of herbicides as a weed control measure.

Treatment vs control

A statistically significantly higher share of control group producers faced weed issues. Moreover, a statistically significantly higher share of control group producers experienced losses in both quantity and quality due to the presence of weeds.

Geographical variation

Geographically, villages situated in the Western Province, specifically in Karongi and Rusizi districts, faced the highest incidence of weed problems, with 78.4 percent and 85.4 percent of producers encountering weeds, respectively. Additionally, these areas also recorded the highest share of producers reporting losses in both quality and quantity due to weed infestations, with 50 percent for Karongi and 50.5 percent for Rusizi. In contrast, producers from Kicukiro district experienced the lowest incidence of weed-related issues, with only 6.3 percent reporting losses due to weeds.

Gender and age

In terms of gender and age categories, the variations were relatively subtle. Females and mature producers had a slightly higher share of encountering weed issues and reporting losses due to weeds. This suggests that the impact of weed infestations is distributed somewhat evenly among different demographic groups.

Losses due to excessive rainfall

A significant portion of producers reported losses associated with rainfall. Specifically, 39.1 percent of producers cited losses due to excessive rainfall (annex 2.3), while 56.9 percent reported losses attributed to insufficient rainfall (Annex 2.4)[24].

Full sample

Regarding excessive rainfall (Annex 2.3), only a small fraction of producers (3.7 percent) reported using improved seeds as a mitigation measure. A majority (57 percent) opted for planting climbing bean varieties, which may offer greater resistance to excessive moisture. It is noteworthy that nearly all producers prepared their soil manually.

Treatment vs control

When examined by producer groups, a statistically significantly higher proportion of control group producers experienced excessive rains and losses in both quantity and quality due to excessive rainfall.

Geographical variation

Geographically, Gakenke district stood out with a considerably higher percentage of producers (84.2 percent) reporting losses attributable to excessive rainfall compared to the national average. Surprisingly, Gakenke's percentage was even higher than that of the neighboring district of Gicumbi, where 47.4 percent of producers reported such losses. Both Gakenke and Gicumbi districts also had the highest share of producers opting for the climbing beans variety, with 85.9 percent and 78.3 percent, respectively.

Gender and age

In terms of gender, male producers reporting losses due to excessive rains were only slightly more prevalent than female producers, with a difference of just 0.8 percentage point. However, youth producers

[24] Annexes 2.3 and 2.4 delve into the repercussions of excessive or insufficient rainfall on bean production, the strategies employed by producers to address these challenges, and the demographics of those affected.

were notably more affected, with a 6.9 percentage point higher incidence of reporting losses due to excessive rainfall compared to mature producers.

The study revealed that manual soil preparation was the predominant method employed in nine out of the ten districts studied. An exception was Nyaruguru district, where 3.33 percent of producers reported using mechanical soil preparation. Notably, all the producers who employed mechanical soil preparation were male and mature.

Losses due to insufficient rain

Annex 2.4 shows the impact of insufficient rainfall on bean production, with a focus on how different factors such as treatment groups, geography, gender, and age groups influence the reported losses.

Full sample

In the analysis of the full sample, it was found that 56.9 percent of all producers faced issues with lack of rain during production. Less than 1 percent of them irrigated their plots, while 4.4 percent utilized improved seeds, and 39.5 percent opted for climbing beans. The study also revealed that manual soil preparation was the predominant method employed.

Treatment vs control

When examining losses attributed to insufficient rainfall by producer groups, treatment groups exhibited a slightly higher incidence, with 59.6 percent of producers reporting losses. In comparison, control groups reported losses from lack of rain at a rate of 55.7 percent.

Geographical variation

Geographically, villages within districts of Kigali City, specifically Kicukiro and Gasabo, faced the highest share of producers reporting losses due to insufficient rainfall. Kicukiro recorded a substantial 83.3 percent of producers reporting such losses, while Gasabo district followed closely with 75.6 percent. In stark contrast, Gakenke district had the lowest incidence of reported losses, standing at only 18.4 percent.

Gender and age

In terms of gender and age groups, a slightly higher share of female and young producers reported encountering losses compared to their male and mature counterparts. Both female and young producers reported around 1 percentage point higher incidence of losses due to insufficient rainfall.

Beans left in the field.

In the case of good quality beans left in the field, the primary reason identified for this loss was the unavailability of affordable labor. It's worth noting that this issue affected only a small number of producers, with three producers from the treatment group and two from the control group reporting beans left in the field.

Post harvest losses.

Beyond pre-harvest losses and crops left in the field, bean producers also grapple with post-harvest losses attributed to various activities such as threshing, drying, winnowing, sorting, storing, transportation, and selling. These losses are not only significant but also multifaceted, driven by a range of factors.

Losses due to tools used.

Quality and suitability of tools used during post-harvest processes played a pivotal role in post-harvest losses. Weather-related challenges, including excessive sun or rain during these activities, were frequently cited as contributing factors. Losses during the harvest, threshing, or winnowing stages were linked to a lack of training and experience among workers. Furthermore, losses due to beans being blown away or spilled, as well as pest infestations, were commonly reported. While storage-related losses were relatively minor, they underlined the complexity of post-harvest challenges within the bean value chain. Annex 2.5 provides critical insights into the post-harvest practices of bean producers such as threshing, winnowing and sifting.

Full sample

An overwhelming 98.5 percent of producers thresh their harvest, all of them employed manual methods, including the use of their hands and simple tools, for threshing their bean harvest. Remarkably, 92.3 percent of these producers reported losses during the threshing process.

Treatment vs control

When examining the data by producer groups, we find no statistically significant difference in the types of tools used in harvesting, threshing, and winnowing, However, a statistically significantly higher share of treatment farmers suffered losses due to both harvesting and threshing.

Geographical variation

Geographically, Bugesera district stood out with the lowest share of producers (93.7 percent) who employed threshing methods, in contrast to other districts. Gisagara district registered the lowest share of producers reporting losses attributed to threshing, with 75.6 percent.

Gender and age

In terms of gender and age groups, a statistically significantly higher share male producers used winnowing tools while a statistically significantly higher share of mature farmers used harvesting tools. A statistically significantly higher share of female producers reported higher threshing-related losses, with a difference of 7.3 percentage points compared to female producers.

Losses at drying practices

Annex 2.6 offers a comprehensive view of bean drying practices, revealing the prevalence of drying activities among producers, the methods employed, and the associated losses. These insights shed light on the challenges faced during the crucial drying stage of bean production.

Full sample

Ninety-eight percent of all producers indicated that they engage in bean drying activities as a crucial part of post-harvest processing. Among these producers, the majority (98.8 percent) opt for traditional floor drying (not hanging), while a small minority (1 percent) choose to hang their bean harvest on the walls and roofs of their homes. Notably, all those employing the hanging method were in Karongi district, accounting for 18.9 percent of producers in that district.

Among the producers who engage in drying activities, 47.5 percent reported experiencing losses during this stage. An overwhelming majority (97.8 percent) of those who incurred losses dried their beans on the floor, while the remaining fraction (2.2 percent) of producers experiencing losses hang their production on walls for drying.

Treatment vs control

When examining the data by producer groups, a notable difference emerges. In the control group, 1.3 percent of producers employ the hanging method for drying, whereas only 0.5 percent of producers in the treatment group adopt this approach. Despite this, a higher percentage of producers in the control group (48.7 percent) reported losses during drying compared to the treatment group (44.5 percent).

Geographical variation

Geographically, villages within Karongi district had the highest percentage of producers (78.4 percent) reporting losses during drying, surpassing other districts. Of significance is the fact that Karongi is the sole district where producers dry their beans by hanging them on the walls of their homes.

Gender and age

In terms of gender and age groups, there were minor variations in the share of producers experiencing losses during drying. Female and mature producers reported slightly lower proportions of losses compared to other demographic groups.

Losses at shelling practices

Annex 2.7 offers insights into the bean shelling practices among producers, shedding light on the prevalence of shelling activities, the types of shelling machines used, and the losses incurred during this stage of bean processing.

Full sample

Nearly all producers interviewed (99.1 percent) engage in shelling activities as a crucial step in bean processing. This underscores the importance of shelling in the post-harvest handling of beans.

In terms of the types of shelling machines used, a vast majority of producers (96.3 percent) rely on manual methods for shelling. Only a small minority (4 percent) opt for mechanical shellers, which provide a more automated and efficient approach to shelling beans.

Despite the prevalence of shelling activities, a significant percentage of producers (63 percent) report experiencing losses during this stage of processing. These losses can have a substantial impact on overall bean production.

Treatment vs control

In the treatment group, 5.9 percent of producers use mechanical shellers, while in the control group, 3.1 percent employ this method. Surprisingly, producers from control villages reported higher instances of shelling-caused losses, with a difference of 3.7 percentage points compared to producers from treatment villages.

Geographical variation

Geographically, Gicumbi district stood out with the highest percentage of producers (7.2 percent) opting for mechanical shelling, indicating a relatively higher adoption of this more efficient shelling method in that region.

Gender and age

In terms of gender and age groups, the use of mechanical shellers is equal between genders, with a slightly higher usage among the youth group (1.3 percentage points).

Losses at storage practices

Annex 2.8 provides valuable insights into bean storage practices, the techniques employed, and the losses incurred during this crucial stage of post-harvest handling. This data offers a comprehensive view of how producers store their beans and the challenges they face.

Full sample

A significant majority of interviewed producers (98 percent) reported that they engage in bean storage as part of post-harvest handling. This underscores the importance of storage in preserving bean quality and availability.

Regarding storage techniques, only a relatively small fraction (12.1 percent) of producers uses modern storage methods, such as PICS bags, supergrain bags, barns, plastic silos, and metallic silos. The vast majority employ traditional storage methods, which include using sacks, uncovered platforms, and underground storage at home.

An overwhelming percentage (99.9 percent) of producers store their bean harvest in their homes. On average, beans are stored for approximately 72 days. This extended storage period further emphasizes the need for effective storage practices.

Among producers who engage in storage, 37.9 percent reported experiencing losses during this phase of post-harvest handling. These losses can significantly impact the overall availability and quality of bean production.

Treatment vs control

A statistically significantly lower share of producers in the treatment group stores their beans compared to the control group. All producers from the treatment group store beans at home, while some producers from the control group also store them on the farm. The average duration of storage for the treatment group is 78 days, slightly longer than the control group's average of 70 days. Regarding producers who reported losses during storage, there are no statistically significant differences between control and treatment groups.

Geographical variation

Geographically, villages in Kicukiro district exhibit a lower level of storage practices (88.9 percent) compared to other districts where nearly all producers in the sample engage in storage. Gasabo and Kicukiro districts predominantly rely on traditional storage methods, while Bugesera district leads in the adoption of modern storage techniques.

Gender and age

In terms of gender, modern storage methods are more commonly practiced by male and mature producers. Male producers using modern storage methods outnumber female producers by 4.8 percentage points, and mature producers using these techniques exceed youth producers by 3.3 percentage points. However, a statistically significantly higher proportion of mature producers reported losses during storage.

Losses at transportation

Annex 2.9 provides insights into the transportation practices employed by bean producers and the losses incurred during this phase of post-harvest handling.

Full sample

A substantial majority of surveyed producers (99.1 percent) indicated that they transport their bean production. This underscores the significance of the transportation stage in ensuring beans reach their intended destinations.

The most popular method of transporting beans, chosen by 95.7 percent of producers, is physical transportation, which includes carrying the production on the head, back, or in the arms. The use of bicycles as a mode of transportation is also common, with 13.1 percent of producers adopting this method. However, it is worth noting that some producers employ multiple transportation methods.

Despite the prevalence of transportation activities, a significant majority (56.9 percent) of producers reported experiencing losses during the transportation phase. These losses can impact the quantity and quality of bean production.

Treatment vs control

The share of producers from treatment villages who reported losses due to transportation was statistically significantly higher, with a 16.5 percentage point difference compared to producers from control villages. Additionally, the treatment group employed motorcycles as a means of transportation, which could have contributed to a reduction in reported losses.

Geographical variation

Geographically, the Eastern province stands out for the widespread use of bicycles as a means of transportation of beans. Specifically, 49.4 percent of producers in Ngoma and 27 percent in Bugesera reported utilizing bicycles. Conversely, Kicukiro district had the lowest percentage, with 33.3 percent of producers reporting losses related to transportation.

Gender and age

In terms of gender and age categories, younger producers had a higher share of those using bicycles for transportation (20 percent) compared to mature producers (11.9 percent). Male producers also had a higher share of bicycle usage (15.2 percent) than female producers (10.1 percent). Notably, a higher share of male and mature producers reported encountering losses during transportation compared to female and young producers, with differences of 4.9 percentage points and 1.0 percentage points, respectively.

Losses at sales practices

Annex 2.10 offers comprehensive insights into the bean sales practices adopted by producers, the activities carried out during the sale of their production, and the losses incurred during this phase.

Full sample

A substantial majority of producers (83.7 percent) indicated that they sold part of their bean production. This highlights the significance of the sales stage in the bean production process. Producers employ various activities to ensure successful sales, including weighing the beans (95.6 percent), sorting them (20.6 percent), advertising (15.3 percent), and conducting rudimentary quality testing (6.6 percent).

Within the group of producers who sold their bean production, 26.3 percent reported losses during the selling phase. These losses were distributed among the four activities performed to facilitate the sale of their beans.

The most common activity during which losses were reported was weighing the beans, with 94 percent of producers reporting losses in this phase. Additionally, 25.8 percent reported losses during sorting, and 16.6 percent during advertising.

Treatment vs control

In the treatment group, 73.9 percent of producers sold their production. In contrast, in the control group, this figure was higher at 87.8 percent, which was statistically significant. However, there were no statistically significant differences in losses due to selling.

Geographical variation

Geographically, Gisagara district had the lowest percentage of producers reporting losses during the selling stage, 13 percent, while Karongi had the highest percentage, with 53.3 percent of producers reporting losses.

Gender and age

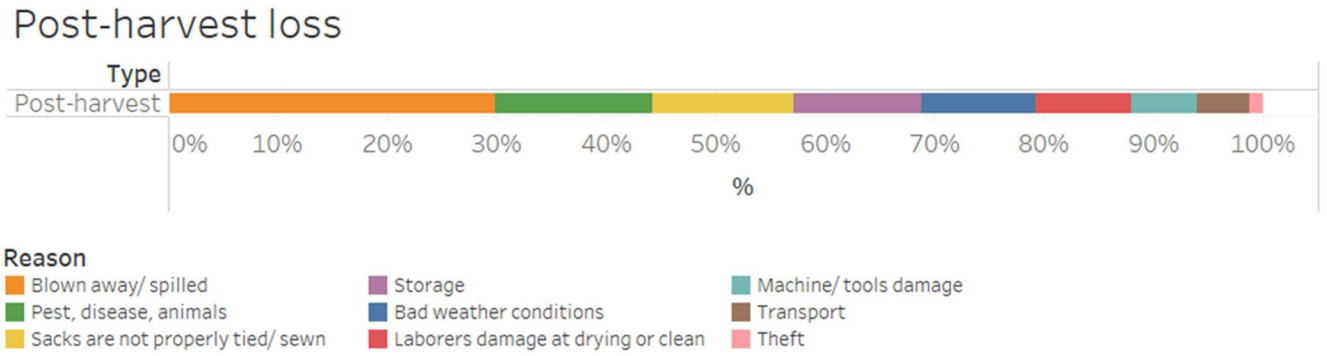
In terms of gender and age categories, a statistically significantly higher share of male producers experienced losses during selling while the differences are not statistically different across age.

Aggregator Stage

Figure 9 presents an analysis of the primary factors cited by aggregators to elucidate post-harvest losses within the bean value chain. The post-harvest activities scrutinized include drying, cleaning and packaging, storage, and distribution and transportation.

Predominantly, these losses stem from beans being blown away or inadvertently spilled during the drying, cleaning and packaging, storage and distribution and transportation phases. Subsequently, challenges arise from the prevalence of pests and diseases across the drying and storage stages, alongside issues stemming from sack malfunction, such as improper tying or sewing, during transportation and storage. Furthermore, adverse weather conditions during the drying process and transportation, compounded by insufficient knowledge among laborers and suboptimal tool conditions during drying and cleaning and packaging, contribute significantly to these losses.

Figure 9: Self-Reported Causes of Losses at the aggregator stage of the beans value chain in Rwanda in 2022- Season A



Source: Authors' calculation using PHL baseline survey (2023).

Processor Stage

Considering the nature of the processors, the causes of losses primarily stem from human factors, including incidents during bean transportation from markets, theft facilitated by inaccurate weight scales, damage to beans caused by fluctuations in storage temperatures, theft, and other related issues.

CONCLUSIONS

The findings of this study underscore the pressing global concern regarding the substantial loss and wastage of food resources. As highlighted in the report, these losses have far-reaching implications, touching upon crucial aspects such as producers' income, the inefficient use of scarce resources, and their subsequent contribution to climate change. Particularly, these losses exacerbate the issue of food insecurity in developing nations, where rapid population growth compounds the challenges. The context of Rwanda, as examined in this study, offers insights into the adverse effects of food losses and waste.

Rwanda, like many countries, grapples with the adverse consequences of food losses. The government acknowledges that a significant portion of its food supply, estimated at approximately 40 percent, is lost due to insufficient post-harvest handling, technical capacity, and facilities. The need to address this issue is apparent, and this study aims to contribute to the understanding and mitigation of these losses, focusing on beans, a vital staple in Rwanda.

The study's methodology, based on the attribute's methodology developed in Delgado et al. (2021), provides a solid framework for data collection and food loss assessment and encompasses three key actors: producers, aggregators, and processors.

Key findings from the study indicate that approximately 60 percent of the surveyed bean producers in Rwanda are males, with an average age nearing 50 years. The representation of youth producers is limited, accounting for only 15 percent of the surveyed population.

The study revealed that the average area sown with beans was 0.36 hectares during the 2023 Season A cropping season. The quantity of beans produced per producer averaged 193.1 kilograms, with an average yield of 910.5 kg/ha. The use of improved seeds was limited, with only 4.1 percent of producers adopting this practice, while 95.5 percent utilized fertilizers at least once. Irrigation was scarcely employed, with just 1.0 percent of producers reporting its used.

Storage practice varied among producers, with approximately 85.7 percent of the producers preparing storage sites, and 56.4 percent engaging in cleaning activities. A significant proportion of producers stored their produce for an average of 2.4 months, primarily in their own dwellings. Male producers tended to employ more modern storage practices. However, the share of beans marketed was relatively low, standing at 32.5 percent of the harvested beans.

In terms of total losses withing the bean value chain, the study revealed a substantial loss of 44.1 percent in volume and 28.5 percent in value. Producers bore the highest share of losses, both in volume and value, while aggregators accounted for the lowest share.

The highest proportion of losses, approximately three-quarters of the volume, occurred at the pre-harvest stage. Therefore, reducing these losses will significantly impact rural livelihoods. Post-harvest losses account for about one-quarter of the total losses in volume. Negligible losses were attributed to beans left in the field, constituting less than 0.2 percent of the output volume. In terms of value, post-harvest losses were more significant, making up 58 percent of the total loss, potentially reflecting increased value addition withing the chain. Pre-harvest losses accounted for 41 percent of the value of beans lost.

Pests and diseases are identified as the primary causes of pre-harvest bean losses, with weather-related challenges also playing a significant role. Pest-related challenges affected three-quarters of bean producers during Season A 2023, despite the application of various pest management practices.

For beans producers of both gender and age groups pre-harvest losses were more important than post-harvest losses. Particularly, female and mature producers encountered weed issues more and females and youth reported higher losses resulting from weeds. Male and youth producers reported losses due

to excessive rains more than females and mature, respectively, while females and youth encountered insufficient rain as a caused for losses.

Post-harvest losses in Rwanda are attributed to various activities including threshing, drying, winnowing, sorting, storing, transportation, and selling. Factors such as the quality and suitability of tools, lack of training and experience among workers, and weather-related challenges contribute significantly to these losses. Over 90 percent of producers reported losses during threshing, while approximately 50 percent experienced losses during bean drying. Manual shelling, practiced by nearly all bean producers in Rwanda, was associated with losses, with 63 percent reporting such losses. The inadequacy or inappropriateness of techniques disproportionately affects male and youth producers, who suffer more during threshing and drying stages. Despite male and mature producers' higher use of modern storage methods, a higher proportion of youth producers experience storage-related losses. Male producers encounter more losses during transportation and sales, while mature producers report more losses during transportation. This, in turn, justifies and highlights the timeliness of plans to improve post-harvest management, handling technology, and infrastructure in Rwanda

The data collected and analyzed in our study indicate the points along the value chain where significant losses occur during pre- and post-harvest and identify the value chain agents engaged in those activities. Although the data collected is not intended to indicate precisely the kinds of interventions needed to ameliorate food losses, inferences can be made from these results. For instance, some of the pre-harvest losses can be managed through a timely and sufficient application of agrochemicals and the use of good quality seeds. Similarly, some causes of post-harvest losses can be better managed through the availability of good quality/ modern tools or storage materials, as well as through capacity building. Dissemination of modern production and post-harvest practices is indispensable across the value chain.

In the context of the project for which this research report is produced, the study provides valuable insights for those engaged in providing interventions intended to reduce pre- and post-harvest losses. Particularly, the results of this study provide evidence supporting the engagement of youth as change agents to reduce food losses, given that the project focuses on engaging youth, particularly young women, in employment across the agri-food systems, particularly in reducing food losses.

In conclusion, this study presents valuable insights into the challenges and losses within Rwanda's bean value chain. It emphasizes the urgent need for targeted interventions and innovations to address the root causes of these losses, empowering producers and enhancing employment opportunities within the value chain. The findings of this study not only benefit Rwanda but also offer lessons and strategies applicable to similar agri-food systems worldwide. This study represents a significant step towards building a more sustainable, efficient, and less wasteful food production and distribution system.

These findings highlight the complex nature of losses in the bean value chain, with varying influences from pest management strategies, geographic location, producer groups, and demographic factors. Tailored interventions and strategies should be developed to address these multifaceted challenges and reduce losses throughout the bean production and distribution process.

It is clear that gender-sensitive and youth-focused agricultural programs and policies are essential. By tailoring interventions to address the unique challenges and opportunities presented by female and youth producers, we can harness their untapped potential and foster inclusivity and sustainability in the agricultural sector. This approach not only empowers these demographic groups but also contributes to the overall growth and resilience of agriculture, ensuring a brighter and more diverse future for the sector.

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ANNEX

Annex 1.1: Design and Final Producer's Sample Distribution at Village Level

Province	District	Sector	Cell	Village	Treatment status	Design Sample size	Final Sample Size
Kigali	Kicukiro	Gahanga	Murinja	Nyabigugu	Control	11	10
		Masaka	Gako	Gihuke	Control	11	8
	Gasabo	Bumbogo	Musave	Kagarama	Control	11	8
			Nkuzuzu	Akasedogo	Control	11	12
		Jabana	Kabuye	Rugarama	Control	11	10
			Ngiryi	Rubona	Control	11	11
South	Nyaruguru	Ngera	Nyamirama	Nyamirama	Control	11	11
			Nyanza	Mpinga	Control	11	11
		Nyagisozi	Maraba	Maraba	Control	11	11
				Rushunguriro	Treatment	14	14
			Nyagisozi	Ryabidandi	Treatment	14	14
		Rusenge	Cyuna	Cyuna	Treatment	14	14
			Rusenge	Kamusindi	Treatment	14	14
	Gisagara	Gishubi	Gabiro	Kigozi	Treatment	14	14
			Nyakibungo	Nyakibungo	Control	11	11
		Ndora	Cyamukuza	Urusenyi	Control	11	11
			Dahwe	Agasharu	Treatment	14	14
			Gisagara	Ndora	Control	11	11
		Save	Munazi	Rwoserezo	Treatment	14	11
			Rwanza	Cyezuburo	Treatment	14	14
West	Karongi	Rugabano	Gisiza	Rubona	Control	11	6
			Kabuga	Karambo	Control	11	5
			Mubuga	Gatwaro	Control	11	3
				Kabyigo	Control	11	7
			Rufungo	Bwihe	Treatment	14	12
			Tyazo	Wurugogwe	Control	11	4
	Rusizi	Rwimbogo	Karenge	Batura	Control	11	16
				Ruzeneko	Control	11	15
			Muhehwe	Renga	Control	11	20
			Mushaka	Gatambamo	Control	11	13
				Nyagashora	Control	11	16

			Ruganda	Ruhinga	Control	11	16
North	Gicumbi	Byumba	Gisuna	Bereshi	Control	11	8
			Kibali	Mugorore	Treatment	14	14
			Nyakabungo	Rugaragara	Control	11	14
		Muko	Cyamuhinda	Gicuregenya	Control	11	11
			Rebero	Karundi	Control	11	11
				Mayogi	Treatment	14	14
		Ruvune	Ruhondo	Kirwa	Control	11	11
				Rwinyana	Treatment	14	14
	Gakenke	Cyabingo	Muhaza	Muhaza	Control	11	11
			Muramba	Bukuba	Control	11	10
			Rukore	Muramba	Control	11	11
		Kivuruga	Cyintare	Nyarubuye	Control	11	11
			Gasiza	Kabuhoma	Control	11	11
				Kamwumba	Control	11	11
				Nturo	Control	11	11
East	Ngoma	Jarama	Karenge	Shirinyota	Control	11	9
			Kigoma	Kigoma	Treatment	14	13
		Karembo	Akaziba	Rwamuhimbura	Control	11	12
			Karaba	Mungoro	Treatment	14	15
			Nyamirambo	Kivugangoma I	Control	11	12
		Sake	Gafunzo	Gatare	Control	11	11
				Rwanyabiranga	Control	11	11
	Bugesera	Musenyi	Gicaca	Gatare	Control	11	11
			Musenyi	Bidudu	Control	11	8
				Gakomeye	Control	11	10
				Kiringa	Control	11	8
				Rugando	Control	11	14
			Nyagihunika	Rugarama	Treatment	14	12

Data source: Laterite,2023

Note: During field implementation, it is important to acknowledge that the distribution design described may have undergone changes to replace producers across villages. This adjustment was typically made when there were insufficient eligible producers in a specific village. In treatment villages, such changes were implemented only after exhausting all available respondents. In control villages, efforts were made to address the lack of eligible respondents in one village by interviewing more respondents in another village within the same cell. However, due to the similarity in conditions among villages in the same cell, additional respondents were ultimately redistributed at higher administrative levels, such as sectors or districts, ensuring an equitable distribution across villages.

Annex 1.2: Final Intermediaries and Processors Sample Distribution at District Level

Province	District	Aggregators Sample Size	Processors Sample Size
Kigali	Kicukiro	2	6
	Gasabo	9	3
Southern	Nyaruguru	23	2
	Huye	4	-
	Gisagara	21	8
Western	Karongi	9	-
	Rusizi	16	3
Northern	Gicumbi	23	1
	Gakenke	10	1
Eastern	Ngoma	12	2
	Bugesera	10	2
	Total	139	28

Data source: Laterite,2023

Annex 1.3: Statistical Tests (t-tests) for Assessing Similarities Among Producer Groups

Variable name			All (N=686)		Treatment (N=203)		Control (N=483)		T-test treatment and control	
			mean	sd	mean	sd	mean	sd		se
Socio-economic characteristics	Gender (male)		59.2%	0.5	65.5%	0.5	56.5%	0.5	0.08**	0.04
	Age (years)		48.4	12.0	49.0	12.2	48.2	11.8	0.00	0.00
	Education[k]	No education	13.3%	0.3	18.2%	0.4	11.2%	0.3	0.13**	0.05
		Primary	71.3%	0.5	67.0%	0.5	73.1%	0.4	-0.06	0.04
		Lower secondary	10.2%	0.3	10.3%	0.3	10.1%	0.3	0.00	0.06
		Upper secondary	4.2%	0.2	3.0%	0.2	4.8%	0.2	-0.09	0.09
		> Secondary	1.0%	0.1	1.5%	0.1	0.8%	0.1	-0.05	0.08
	Household size		5.4	2.1	5.3	2.0	5.4	2.1	-0.01	0.01
	Main occupation	Farming	98.5%	0.1	100%	0.0	97.9%	0.1	0.30**	0.15
		Petty Trade	0.4%	0.1	0%	0.0	0.6%	0.1	-0.30	0.26
		Education related	0.6%	0.1	0%	0.0	0.8%	0.1	0.26	0.23
		Religious related	0.3%	0.1	0%	0.0	0.4%	0.1	-0.30	0.32
		Private sector	0.1%	0.0	0%	0.0	0.2%	0.0	-0.30	0.46
	Experience in cultivating beans (years)		20.6	12.8	20.7	12.8	20.6	12.8	0.00	0.00
Production	Quantity produced last harvest (Kg)		193.1	226.5	193.5	203.2	192.9	235.9	2.50E-06	0.00
	Area cultivated (in hectares)		0.36	0.37	0.36	0.41	0.36	0.35	-0.01	0.05
	Yield (kg/ha)		910.5	898.3	980.9	954.5	880.9	873.0	0.00	0.00
	Improved seeds (dummy)		4.1%	0.2	4.9%	0.2	3.7%	0.2	0.06	0.09
	Climbing beans (dummy)		45.2%	0.5	41.8%	0.5	46.5%	0.5	-0.04	0.04
	Number of different inputs applied		1.5	0.8	1.4	0.7	1.6	0.8	-0.05**	0.02
	Number of different field maintenance activities		0.0	0.2	0.0	0.2	0.0	0.2	0.00	0.11
	Soil preparation	Manual	99.7%	0.1	100%	0.0	99.6%	0.1	0.30	0.32
		Draught animals	0.3%	0.1	0%	0.1	0.2%	0.0	0.20	0.32
		Mechanical	0.1%	0.0	0%	0.0	0.2%	0.0	-0.30	0.46
	Fertilizer Application	Once	95.5%	0.2	97%	0.2	95.0%	0.2	0.07	0.08
		Twice	24.2%	0.4	20%	0.4	25.9%	0.4	-0.06	0.04
		Three times	0.4%	0.1	0%	0.0	0.6%	0.1	-0.30	0.26
	Foliar Application		0.3%	0.1	0%	0.0	0.4%	0.1	-0.30	0.32
	Irrigation		1.0%	0.1	1%	0.1	1.0%	0.1	-0.01	0.17
	Number of mechanic production activities		0	0	0	0	0	0	-	-
	Agricultural cooperative membership		20.1%	0.4	32.7%	0.5	15.8%	0.4	0.20***	0.04
	Hired labor		86.6%	0.3	82.8%	0.4	88.2%	0.3	-0.09*	0.05
Post-harvest	Nb of post-harvest activities		6.8	0.6	6.7	0.6	6.8	0.6	-0.09***	0.03
	Post-harvest activity - cleaning storage		56.4%	0.5	43.8%	0.5	61.7%	0.5	-0.15***	0.03
	Post-harvest activity - preparing storage site		85.7%	0.4	80.3%	0.4	88.0%	0.3	-0.13***	0.05
	Storage (dummy)		98.0%	0.1	96.6%	0.2	98.6%	0.1	-0.21*	0.12
	Storage time (in days)		72.0	83.3	77.7	142.1	69.6	37.2	0.00	0.00
	Storage location	House (bag)	99.7%	0.1	100.0%	0.0	99.6%	0.1	0.29	0.46
	Storage type	Modern	12.1%	0.3	11.7%	0.3	12.2%	0.3	-0.01	0.05
		PICS bags	90.1%	0.3	87.0%	0.3	91.4%	0.3	-0.02	0.06
		Barns at home	1.2%	0.1	4.3%	0.2	0.0%	0.0	0.71	0.46
	Type of modern storage containers	Metallic silos	3.7%	0.2	4.3%	0.2	3.4%	0.2	0.04	0.26
		Plastic silos	3.7%	0.2	4.3%	0.2	3.4%	0.2	0.04	0.26
		Supergrain bag	1.2%	0.1	0.0%	0.0	1.7%	0.1	-0.3	0.46
Sales	Percentage of harvest sold		32.5%	0.2	28.9%	0.3	34.0%	0.2	-0.18**	0.07
	Type of buyer the farmer sells to	Middlemen	56.1%	0.5	60.9%	0.5	54.3%	0.5	0.0	0.04
		Processor	1.0%	0.1	0.9%	0.1	1.0%	0.1	0.0	0.23
		Store	23.3%	0.4	25.5%	0.4	22.5%	0.4	0.0	0.05
		Consumer	23.3%	0.4	15.5%	0.4	26.2%	0.4	-0.14***	0.05
	Nb of transactions to sell last harvest		1.7	8.4	2.9	16.1	1.3	0.9	0.004	0.00

Note: ***p<0.01, ** p<0.05, * p<0.1

Annex 2.1: Producers Reporting Pre-Harvest Losses Due to Pests and Diseases, and Utilization of Pest Management Strategies

				% of pest management						Producers reporting losses in quality and quantity				
		Pest issue	Pest Management	Use of chemical insecticide or pesticide	Use of biological pesticides	Use of Integrated pest management	Use of fungicides	Use of biological insecticides	Producers reporting losses due to pests/ diseases	Applied chemical insecticide	Applied biopest	Applied integrated pest management	Applied fungicides	Applied biological insecticides
All		**74.2**	**32.7**	**92.4**	**13.8**	**3.6**	**4.5**	**2.1**	**54.2**	**35.8**	**4.0**	**2.0**	**1.7**	**2.9**
	Treatment Villages	72.9	26.1	94.3	7.6	3.8	3.8	3.8	52.7	32.7	1.0	2.0	2.0	2.0
	Control Villages	74.7	35.4	91.8	15.8	3.5	4.7	1.8	54.8	37.1	5.2	2.0	1.6	3.2
Districts	Gasabo	61.0	29.3	100.0	0.0	0.0	0.0	0.0	42.5	23.5	0.0	0.0	0.0	0.0
	Kicukiro	44.4	22.2	75.0	25.0	0.0	0.0	0.0	31.3	40.0	0.0	0.0	0.0	0.0
	Gisagara	79.1	36.1	100.0	6.5	0.0	6.5	0.0	52.0	45.0	2.5	0.0	2.5	5.0
	Nyaruguru	69.7	18.0	87.5	12.5	12.5	12.5	12.5	54.7	19.2	0.0	4.3	4.3	4.3
	Karongi	86.5	51.4	100.0	0.0	5.3	0.0	0.0	69.4	56.0	0.0	4.0	0.0	0.0
	Rusizi	87.5	36.5	94.3	11.4	5.7	8.6	8.6	75.8	36.1	4.2	1.4	4.2	8.3
	Gakenke	90.8	67.1	98.0	21.6	0.0	3.9	0.0	52.7	64.1	18.0	0.0	0.0	0.0
	Gicumbi	59.8	23.7	87.0	17.4	8.7	0.0	0.0	47.3	27.3	4.6	4.6	0.0	0.0
	Ngoma	73.5	28.9	83.3	16.7	0.0	0.0	0.0	48.7	29.0	0.0	0.0	0.0	0.0
	Bugesera	66.7	14.3	55.6	33.3	11.1	11.1	0.0	44.9	18.2	4.6	4.6	0.0	0.0
Gender	Male	74.6	33.5	92.7	9.6	4.4	5.9	0.7	55.1	36.8	2.8	2.4	2.4	2.4
	Female	73.6	31.4	92.1	20.5	2.3	2.3	4.6	52.9	34.3	5.8	1.5	0.7	3.7
Age category	Youth (35 and less)	83.0	40.0	92.5	15.0	7.5	2.5	3.3	61.5	30.5	5.1	3.4	0.0	1.7
	Mature (Above 35)	72.7	31.4	92.4	13.6	2.7	4.9	1.5	52.9	36.9	3.8	1.7	2.1	3.1

Annex 2. 2: Producers Reporting Pre-Harvest Losses Due to Weed Infestation

		Weeds issue	Method of controlling weeds		Producers reporting losses in quality and quantity due to weeds	Producers who control weeds manually that report losses due to weeds
			Chemical herbicides	Manual control		
All		**65.2**	**0**	**97.4**	**26.7**	**37.8**
	Treatment	61.6	0	98.5	19.9	28.7
	Control	66.7	0	96.9	29.5	41.3
Districts	**Gasabo**	61.0	0	96.2	12.5	16
	Kicukiro	72.2	0	92.9	6.3	0
	Gisagara	75.6	0	98.5	31.2	41.4
	Nyaruguru	60.7	0	98.2	24.4	35.9
	Karongi	78.4	0	100	50.0	64
	Rusizi	85.4	0	98.8	50.5	59
	Gakenke	71.1	0	100	23.0	26
	Gicumbi	27.8	0	100	15.1	39
	Ngoma	63.9	0	96.2	11.5	12.8
	Bugesera	71.4	0	89.4	30.6	45.2
Gender of producers	**Male**	64.3	0	97.4	25.5	35.9
	Female	66.4	0	97.4	28.6	40.6
Age category of producer	**Youth (35 and less)**	65.0	0	100	29.2	41.9
	Mature (Above 35)	65.2	0	97.0	26.3	37.1

Annex 2.3: Producers Reporting Pre-Harvest Losses Due to Excessive Rain, Type of Beans Used, and Soil Preparation Practices

		Producers who encountered excessive rain issues during production (% of total sample)	Producers reporting excessive rain issues who irrigated their plots (% of total)	Producers who reported excessive rain and used improved seeds (%)	Producers reporting excessive rain issues who planted climbing beans (%)	Soil Preparation (% of producers reported excessive rains)		
						Manual soil preparation	Mechanical soil preparation	Soil preparation using animals
All		**39.1**	**0.8**	**3.7**	**57.0**	**99.6**	**0.4**	**0.0**
	Treatment	31.0	0	3.2	48.4	100.0	0.0	0.0
	Control	42.4	1.0	3.9	59.6	99.5	0.5	0.0
Districts	**Gasabo**	14.6	16.7	16.7	33.3	100.0	0.0	0
	Kicukiro	5.6	0	0.0	0.0	100.0	0.0	0
	Gisagara	10.5	0	0.0	0.0	100.0	0.0	0
	Nyaruguru	33.7	0	3.3	73.3	96.7	3.33	0
	Karongi	37.8	0	0.0	57.1	100.0	0.0	0
	Rusizi	54.2	0	9.6	42.0	100.0	0.0	0
	Gakenke	84.2	1.6	3.1	85.9	100.0	0.0	0
	Gicumbi	47.4	0	2.2	78.3	100.0	0.0	0
	Ngoma	47.0	0	0.0	15.8	100.0	0.0	0
	Bugesera	11.1	0	0.0	14.3	100.0	0.0	0
Gender of producers	**Male**	39.4	1.3	3.8	54.4	99.4	0.6	0
	Female	38.6	0	3.7	60.8	100.0	0.0	0
Age category of producer	**Youth (35 and less)**	45.0	2.2	2.2	60.5	100.0	0.0	0
	Mature (Above 35)	38.1	0.45	4.0	56.3	99.6	0.5	0

Annex 2.4: Producers Reporting Pre-Harvest Losses Due to Lack of Rain, Type of Beans Used, and Soil Preparation Practices

		Producers who encountered lack of rain issues during production (%)	Producers who irrigated their plots (%)	Producers who reported lack of rain and used improved seeds (%)	Producers reporting lack of rain issues who planted climbing beans (%)	Soil Preparation (% of producers reported lack of rain)		
						Manual soil preparation	Mechanical soil preparation	Soil preparation using animals
All		**56.9**	**0.8**	**4.4**	**39.5**	**99.5**	**0.3**	**0.5**
	Treatment	59.6	0.0	6.6	39.5	100.0	0.0	0.8
	Control	55.7	1.1	3.4	39.5	99.3	0.4	0.4
Districts	**Gasabo**	75.6	0.0	3.2	32.3	96.8	0.0	3.2
	Kicukiro	83.3	0.0	0.0	0.0	100.0	0.0	0
	Gisagara	74.4	0.0	1.6	9.4	100.0	0.0	0
	Nyaruguru	62.9	0.0	8.9	76.6	98.2	1.79	0
	Karongi	62.2	0.0	4.4	82.6	100.0	0.0	4.4
	Rusizi	63.5	1.6	4.9	45.0	100.0	0.0	0
	Gakenke	18.4	7.1	7.1	85.7	100.0	0.0	0
	Gicumbi	46.4	0.0	4.4	64.4	100.0	0.0	0
	Ngoma	50.6	2.4	4.8	21.4	100.0	0.0	0
	Bugesera	61.9	0.0	2.6	5.1	100.0	0.0	0
Gender of producers	**Male**	56.5	0.9	4.8	44.1	99.1	0.4	1
	Female	57.1	0.6	3.8	32.9	100.0	0.0	0
Age category of producer	**Youth (35 and less)**	58.0	1.7	6.9	45.6	100.0	0.0	1
	Mature (Above 35)	56.7	0.6	3.9	39.5	99.4	0.3	0

Annex 2.5: Threshing, Winnowing and Sifting Practices of Harvested Beans, and Associated Losses Due to Threshing

		Producers who thresh their harvest (%)	Producers who thresh their harvest by hand and simple tool (%)	Producers who reported losses due to threshing (%)	Producers reporting losses who thresh by hand and simple tools
All		**98.5**	**100**	**92.3**	**100**
	Treatment	98.5	100	86	100
	Control	98.6	100	95.0	100
Districts	**Gasabo**	100	100	92.7	100
	Kicukiro	94.4	100	94.1	100
	Gisagara	100.0	100	75.6	100
	Nyaruguru	100	100	86.5	100
	Karongi	97.3	100	97.2	100
	Rusizi	99.0	100	97.9	100
	Gakenke	98.7	100	96.0	100
	Gicumbi	99.0	100	95.8	100
	Ngoma	98.8	100	98.8	100
	Bugesera	93.7	100	93.2	100
Gender of producers	**Male**	99.0	100	95.3	100
	Female	97.9	100	88.0	100
Age category of producers	**Youth (35 and less)**	100.0	100	94.0	100
	Mature (Above 35)	98.3	100	92.0	100

Annex 2.6: Drying Practices of Harvested Beans, Techniques of Drying, and Associated Losses

			Solar drying technique		Solar drying technique		
		Producers who dry their harvest (%)	Drying by not hanging their production (%)	Drying by hanging their production (%)	Producers who report losses during drying - Quantity and quality losses (%)	Producers reporting losses who dry by not hanging their production (%)	Producers reporting losses who dry by hanging their production (%)
All		**98.3**	**98.8**	**1.0**	**47.5**	**97.8**	**2.2**
Treatment		98.5	99.5	0.5	44.5	98.9	1.1
Control		98.1	98.5	1.3	48.7	97.4	2.6
Districts	**Gasabo**	100.0	100.0	0.0	43.9	100.0	0
	Kicukiro	94.4	100.0	0.0	11.8	100.0	0
	Gisagara	100.0	100.0	0.0	27.9	100.0	0
	Nyaruguru	98.9	98.9	0.0	38.6	100.0	0
	Karongi	100.0	81.1	18.9	78.4	75.9	24.1
	Rusizi	99.0	100.0	0.0	65.3	100.0	0
	Gakenke	100.0	100.0	0.0	59.2	100.0	0
	Gicumbi	94.9	100.0	0.0	47.8	100.0	0
	Ngoma	100.0	100.0	0.0	47.0	100.0	0
	Bugesera	93.7	100.0	0.0	39.0	100.0	0
Gender of producers	**Male**	98.3	99.0	1.0	48.1	97.9	2.1
	Female	98.2	98.6	1.1	46.6	97.7	2.3
Age category of producers	**Youth (35 and less)**	100.0	98.0	2.0	52.0	96.2	3.9
	Mature (Above 35)	98.0	99.0	0.9	46.7	98.1	1.9

Annex 2.7: Shelling Practices of Harvested Beans, Techniques of Shelling, and Associated Losses

			Type of shelling machine			Losses in quality and quantity	
		Producers who shell their beans (%)	Mechanical shellers (%)	Manual shellers (%)	Producers reporting losses due to shelling (%) - Quantity and quality losses (%)	Mechanical shellers (%)	Manual shellers (%)
All		**99.1**	**4.0**	**96.3**	**63.0**	**3.3**	**97.0**
Treatment		99.5	5.9	94.1	60.4	3.3	96.7
Control		99.0	3.1	97.3	64.1	3.3	97.1
Districts	**Gasabo**	100.0	2.4	97.6	70.7	3.5	96.6
	Kicukiro	94.4	0.0	100.0	64.7	0.0	100.0
	Gisagara	100.0	5.8	94.2	43.0	5.4	94.6
	Nyaruguru	98.9	3.4	96.6	59.6	1.9	98.1
	Karongi	100.0	2.7	97.3	75.7	0.0	100.0
	Rusizi	100.0	2.1	97.9	71.9	1.5	98.6
	Gakenke	100.0	2.6	98.7	69.7	1.9	100.0
	Gicumbi	100.0	7.2	93.8	57.7	5.4	94.6
	Ngoma	100.0	4.8	95.2	74.7	6.5	93.6
	Bugesera	93.7	3.4	96.6	52.5	3.2	96.8
Gender of producers	**Male**	99.5	4.0	96.3	64.4	3.5	96.9
	Female	98.6	4.0	96.4	60.9	3.0	97.0
Age category of producers	**Youth (35 and less)**	99.0	5.1	95.0	64.0	3.1	96.9
	Mature (Above 35)	99.2	3.8	96.6	62.8	3.3	97.0

Annex 2. 8: Storage Practices of Harvested Beans, Modes and Locations of Storage, Average Storage Time, and Associated Losses

		Producers that store (%)	Storage Technique of producers who store		Location of the storage		Average storage time (days)	Producers who reported losses at storage (%)	Producers reporting losses at storage (by storage type)	
			Modern (%)	Traditional (%)	Store at home (%)	Stored on Farm (%)			Modern storage (%)	Traditional Storage (%)
All		**98.0**	**12.1**	**87.8**	**99.9**	**0.2**	**72.0**	**30.4**	**8.8**	**91.2**
Treatment		96.6	11.7	88.3	100.0	0.0	80.5	28.1	7.3	92.7
Control		98.6	12.2	87.6	99.8	0.2	70.7	31.3	9.4	90.6
Districts	**Gasabo**	100.0	0.0	100.0	97.6	2.4	96.4	39.0	0	100.0
	Kicukiro	88.9	0.0	100.0	100	0.0	67.3	50.0	0	100.0
	Gisagara	95.4	6.1	93.9	100	0.0	79.6	17.1	7.1	92.9
	Nyaruguru	98.9	11.4	88.6	100	0.0	80.0	26.1	4.4	95.7
	Karongi	100.0	16.2	83.8	100	0.0	76.3	13.5	20.0	80.0
	Rusizi	99.0	15.8	84.2	100	0.0	66.6	32.6	25.8	74.2
	Gakenke	100.0	10.5	88.2	100	0.0	71.5	38.2	6.9	93.1
	Gicumbi	97.9	17.9	82.1	100	0.0	80.2	37.9	11.1	88.9
	Ngoma	100.0	10.8	89.2	100	0.0	69.9	39.8	0.0	100.0
	Bugesera	93.7	18.6	81.4	100	0.0	47.5	15.3	11.1	88.9
Gender of producers	**Male**	98.3	14.0	86.0	100	0.0	77.7	30.8	10.6	89.4
	Female	97.5	9.2	90.5	99.8	0.2	67.3	29.7	6.2	93.8
Age category of producers	**Youth (35 and less)**	98.0	9.2	90.8	100.0	0.0	72.9	45.9	11.3	88.7
	Mature (Above 35)	98.0	12.5	87.3	99.6	0.4	73.6	27.7	13.7	86.3

* Modern storage includes PICS bags, supergrain bags, barns, plastic silos and metallic silos.
* Traditional storage includes storing in sacks, uncovered platforms and underground at home.

Annex 2. 9: Transportation Practices of Harvested Beans, Mode of Transportation, and Reported Losses Due to Transportation Activities

		Producers that transport their production (%)	Transportation Methods				Producers reporting losses during transportation (%)	Producers reporting losses by physically carrying their production (%)	Producers reporting losses by using trucks and carts for transportation (%)	Producers reporting losses by using bicycles for transportation (%)	Producers reporting losses by using motorbicycles for transportation (%)
			Carry physically (%)	Manual trucks, carts or wheelbarrows (%)	Bicycles (%)	Motorbicycles (%)					
All		**99.1**	**95.7**	**0.3**	**13.1**	**0.6**	**56.9**	**95.1**	**0.3**	**14.7**	**0.5**
Treatment		99.0	95.5	0.5	14.9	1.0	45.3	93.4	0.0	19.8	2.2
Control		99.2	95.8	0.2	12.3	0.4	61.8	95.6	0.3	13.2	0.0
Districts	**Gasabo**	100.0	100.0	0.0	2.4	0.0	58.5	100.0	0.0	0.0	0.0
	Kicukiro	100.0	100.0	0.0	0.0	0.0	33.3	100.0	0.0	0.0	0.0
	Gisagara	98.8	96.5	0.0	14.1	2.4	41.2	94.3	0.0	20.0	2.9
	Nyaruguru	100.0	100.0	0.0	7.9	0.0	34.8	100.0	0.0	12.9	0.0
	Karongi	97.3	100.0	0.0	2.8	0.0	72.2	100.0	0.0	3.9	0.0
	Rusizi	97.9	96.8	0.0	6.4	0.0	62.5	96.6	0.0	5.1	0.0
	Gakenke	98.7	100.0	0.0	0.0	0.0	77.3	100.0	0.0	0.0	0.0
	Gicumbi	99.0	99.0	1.0	4.2	1.0	54.2	100.0	1.9	0.0	0.0
	Ngoma	100.0	86.8	1.2	49.4	1.2	68.7	89.5	0.0	49.1	1.8
	Bugesera	100.0	82.5	0.0	27.0	0.0	61.9	76.9	0.0	35.9	0.0
Gender of producers	**Male**	99.0	96.0	0.5	15.2	0.8	58.9	95.4	0.4	17.3	0.4
	Female	99.3	95.3	0.0	10.1	0.4	54.0	94.7	0.0	10.7	0.7
Age category of producers	**Youth (35 and less)**	100.0	93.0	0.0	20.0	0.0	56.0	91.1	0.0	21.4	0.0
	Mature (Above 35)	99.0	96.2	0.3	11.9	0.7	57.0	95.8	0.3	13.6	0.6

Annex 2.10: Selling Practices of Harvested Beans, Locations of Selling, and Associated Losses

		Producers that sold their beans (%)	Producers who advertised while selling their product (%)	Producers who sorted their beans during selling (%)	Producers who conducted rudimentary quality tests during selling (%)	Producers who weighed their products while selling (%)	Producers reporting losses during selling (%)	Producers reporting losses during advertising (%)	Producers reporting losses during sorting (%)	Producers reporting losses during quality testing (%)	Producers reporting losses during weighing (%)
All		**83.7**	**15.3**	**20.6**	**6.6**	**95.6**	**26.3**	**16.6**	**25.8**	**0.7**	**94.0**
Treatment		73.9	15.3	20.0	9.3	98.0	24.0	2.8	27.8	0.0	97.2
Control		87.8	15.3	20.8	5.7	94.8	27.1	20.9	25.2	0.9	93.0
Districts	**Gasabo**	78.1	9.4	3.1	0.0	100.0	25.0	0.0	0.0	0.0	100.0
	Kicukiro	27.8	0.0	0.0	0.0	100.0	40.0	0.0	0.0	0.0	100.0
	Gisagara	62.8	14.8	20.4	1.9	100.0	13.0	14.3	0.0	0.0	100.0
	Nyaruguru	85.4	21.1	23.7	14.5	96.1	30.3	21.7	39.1	0.0	100.0
	Karongi	81.1	3.3	43.3	0.0	100.0	53.3	0.0	31.3	0.0	100.0
	Rusizi	100.0	6.3	24.0	0.0	93.8	30.2	17.2	20.7	0.0	100.0
	Gakenke	97.4	28.4	17.6	13.5	83.8	27.0	55.0	20.0	5.0	60.0
	Gicumbi	88.7	11.6	23.3	10.5	100.0	22.1	0.0	42.1	0.0	100.0
	Ngoma	100.0	19.3	18.1	3.6	98.8	24.1	10.0	30.0	0.0	100.0
	Bugesera	60.3	18.4	10.5	10.5	92.1	18.4	14.3	14.3	0.0	85.7
Gender of producers	**Male**	83.3	15.1	21.0	6.2	95.6	23.4	13.9	26.6	0.0	93.7
	Female	84.3	15.7	19.9	7.2	95.8	30.5	19.4	25.0	1.4	94.4
Age category of producers	**Youth (35 and less)**	87.0	14.9	24.1	6.9	96.6	32.2	14.3	21.4	0.0	92.9
	Mature (Above 35)	83.1	15.4	19.9	6.6	95.5	25.3	17.1	26.8	0.8	94.3

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