Rwanda Food Smart Country Diagnostic

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Rwanda Food Smart Country Diagnostic

Executive Summary

The term “food smart” refers to a food system that is efficient, meets the food needs of a country, and is environmentally sustainable. Reducing food loss and waste (FLW) is one of the critical pillars of building a smart food system. This diagnostic focuses on the FLW pillar, from farm to fork to landfill, with the objective of alerting policymakers to the role that addressing food loss and waste can play in meeting their various global and national policy commitments.

FLW is a global problem; estimates suggest that 25-30% of all food produced is never eaten, generating around 8-10% of annual global greenhouse gas emissions.* According to the United Nations, food that is lost closer to the farm (in contrast to consumer waste), equates to an annual economic loss of USD 400 billion.**

Across Sub-Saharan Africa, FLW contributes to food insecurity, reduced income to farmers and communities, and greenhouse gas emissions. In Rwanda specifically, a growing population — set to nearly double to 22 million in the next 30 years — will exacerbate the food security challenge. Even today, undernourishment affects 35.6% of Rwanda’s population, and 36.9% of children are stunted.

Three intervention strategies for addressing Rwanda food availability are 1) increased yield from expanded natural resource use or increased yields from resources already under production, 2) food imports, and 3) reduced FLW. Limited unfarmed land, the need for investment in farming techniques, and the effects of climate change undercut a yield-increase strategy. Disruption in trade balances and domestic food prices, Rwanda’s insufficient trade infrastructure, and limited access to vulnerable rural populations constrain the benefits of a food import strategy.

Reducing food loss and waste is one promising strategy for improving food security and generating additional, positive impacts. Currently, Rwanda loses and wastes 40% of total food production each year. This represents 21% of its total land use, 16% of its greenhouse gas emissions, and a 12% loss to Rwanda’s annual GDP. Rwanda currently has international treaty commitments to reduce food loss and waste.

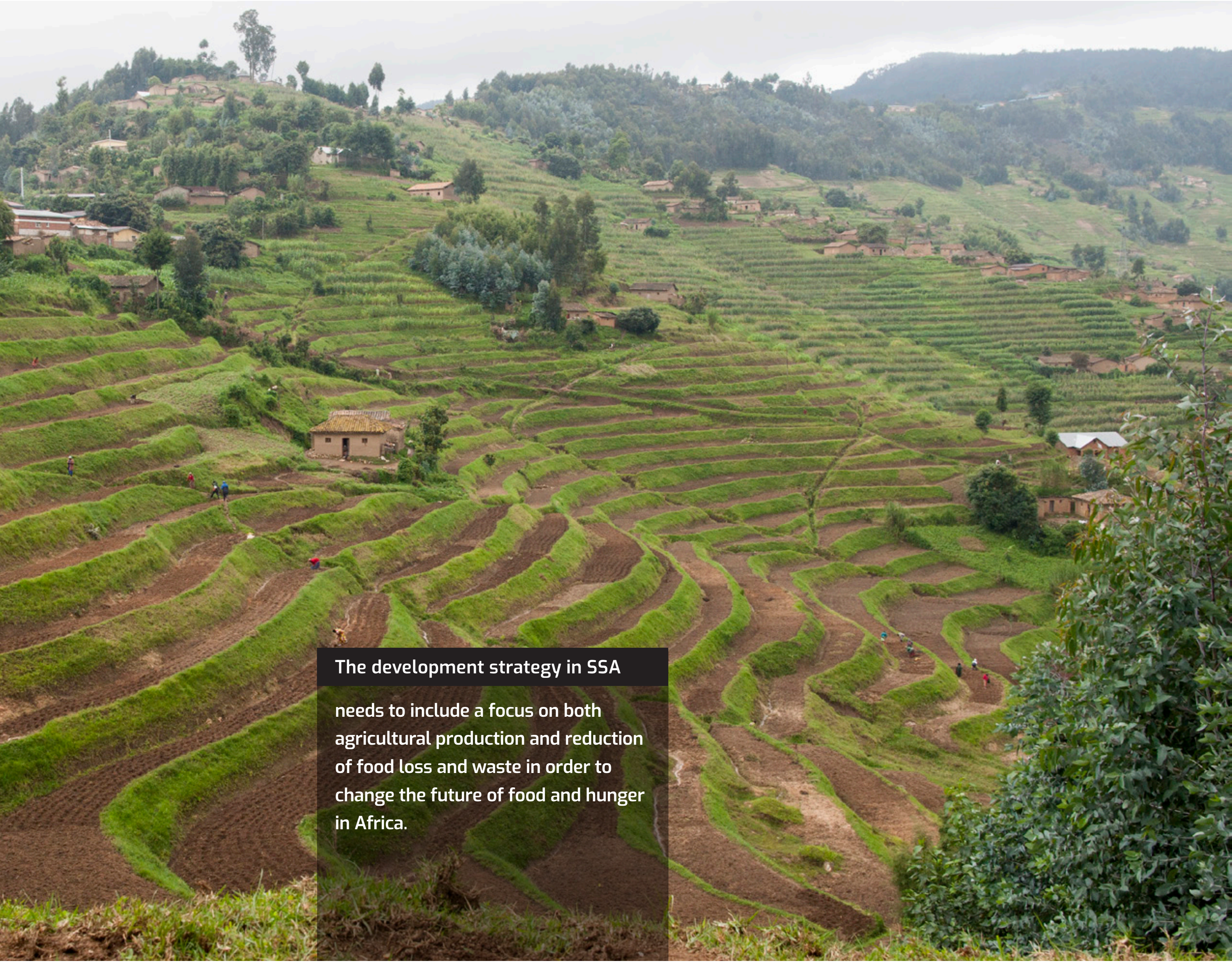
CONTENTS

*United Nations Intergovernmental Panel on Climate Change (2019). *Special Report on Climate Change and Land.* Chapter 5: Food Security. Accessed: October 23, 2019. https://www.ipcc.ch/site/assets/uploads/2019/08/2f.-Chapter-5_FINAL.pdf

**Bloomberg (2019). *The World Loses $400 Billion of Food Before It Reaches Stores.* By Agnieszka de Sousa. Accessed: October 23, 2019. https://www.bloomberg.com/news/articles/2019-10-14/the-world-loses-400-billion-of-food-before-it-reaches-stores

This report examines losses of tomatoes (perishables) and maize and rice (staples), using the World Bank's Global Framework economic model to assess how reductions in losses along the value chain of these commodities affect Rwanda's competing policy priorities. **Importantly, the analysis finds that Rwanda will not face a negative tradeoff between reducing FLW and achieving, at the same time, its policy objectives of farmer welfare, food security, trade, natural resource stress, greenhouse gas emissions, and food waste.**

The diagnostic highlights the role that *the perception of risk* plays in exacerbating food loss and waste in Rwanda. This dynamic suggests the importance of risk-reducing policy interventions across the value chain, such as access to real-time information and education for farmers. Other recommendations include improved infrastructure, increased cooling and refrigeration capacity, and an urban waste strategy.



Sub-Saharan Africa: A Regional Overview

A rapidly growing population and changing diets in Sub-Saharan Africa (SSA) are driving food consumption and imposing significant demand on the continent's water, land, and energy needs. Out of a population of one billion, 60% live in rural areas,[1] and around 578 million are moderately or severely food insecure.[2] Climate change threatens to undermine the ability of agricultural food systems to adapt and grow in the face of long-term stresses and climate variability.

Food loss and waste—particularly post-harvest losses—is a development challenge in Africa (Figure 1).[3] It exacerbates food insecurity, reduces income to farmers and communities, and wastes precious land, water, and energy resources without generating human benefits while increasing greenhouse emissions. The total quantitative food loss in sub-Saharan Africa has been estimated at 37% post-harvest, or 100 million metric tons per year. For grains alone, the value of post-harvest losses is estimated to equate to approximately USD 4 billion per year.[4] These levels of losses are enough to meet the annual food requirements of about 48 million people and they exceed the annual value of grain imports into Africa. The value of losses also exceeds the value of total food aid received in sub-Saharan Africa over the past decade.[5]

Food losses are varied per commodity type, as shown in Figure 2,[6] where losses are highest for fruits and vegetables at around 50%, and the least for cereals and grains at around 20%.

The development strategy in SSA needs to include a focus on both agricultural production and reduction of food loss and waste in order to change the future of food and hunger in Africa.

FIGURE 1. Post-harvest losses dominate in SSA (% of losses)

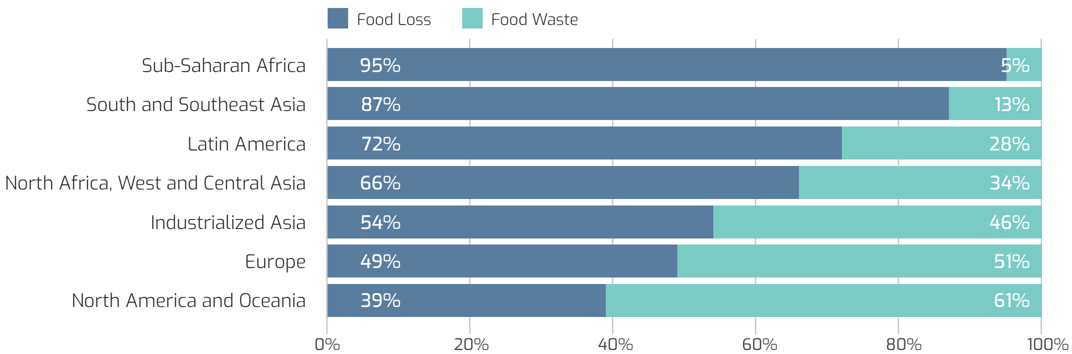
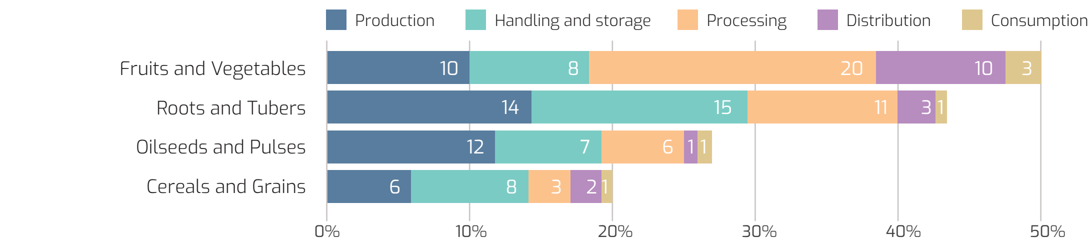


FIGURE 2. Food loss and waste by crop in SSA (% of production lost or wasted)



Source: Deloitte, 2015

Rwanda's Challenge: Feeding Its People

One of Rwanda's primary challenges is to feed its population, set to nearly double in numbers from 12 million today[7] to 22 million in the next 30 years.[8] Despite significant progress since the early 1990s, even at today's numbers, Rwanda's people remain challenged by food insecurity, malnutrition and undernourishment. Rwanda's food security index lies below the average for Sub-Saharan African countries. Some 18.7% of Rwandan households remain food insecure today,[9] with most of them located in the western and northern parts of the country. Undernourishment affects 35.6% of the population and 36.9% of children are stunted.[10] The food challenge will be compounded by the rapid urbanization of the country. By 2050, 30% of the population will reside in urban areas[11] with prospects of higher incomes, and food consumption will shift toward higher value diets, with more standardized and processed food, as well as a greater focus on food safety.

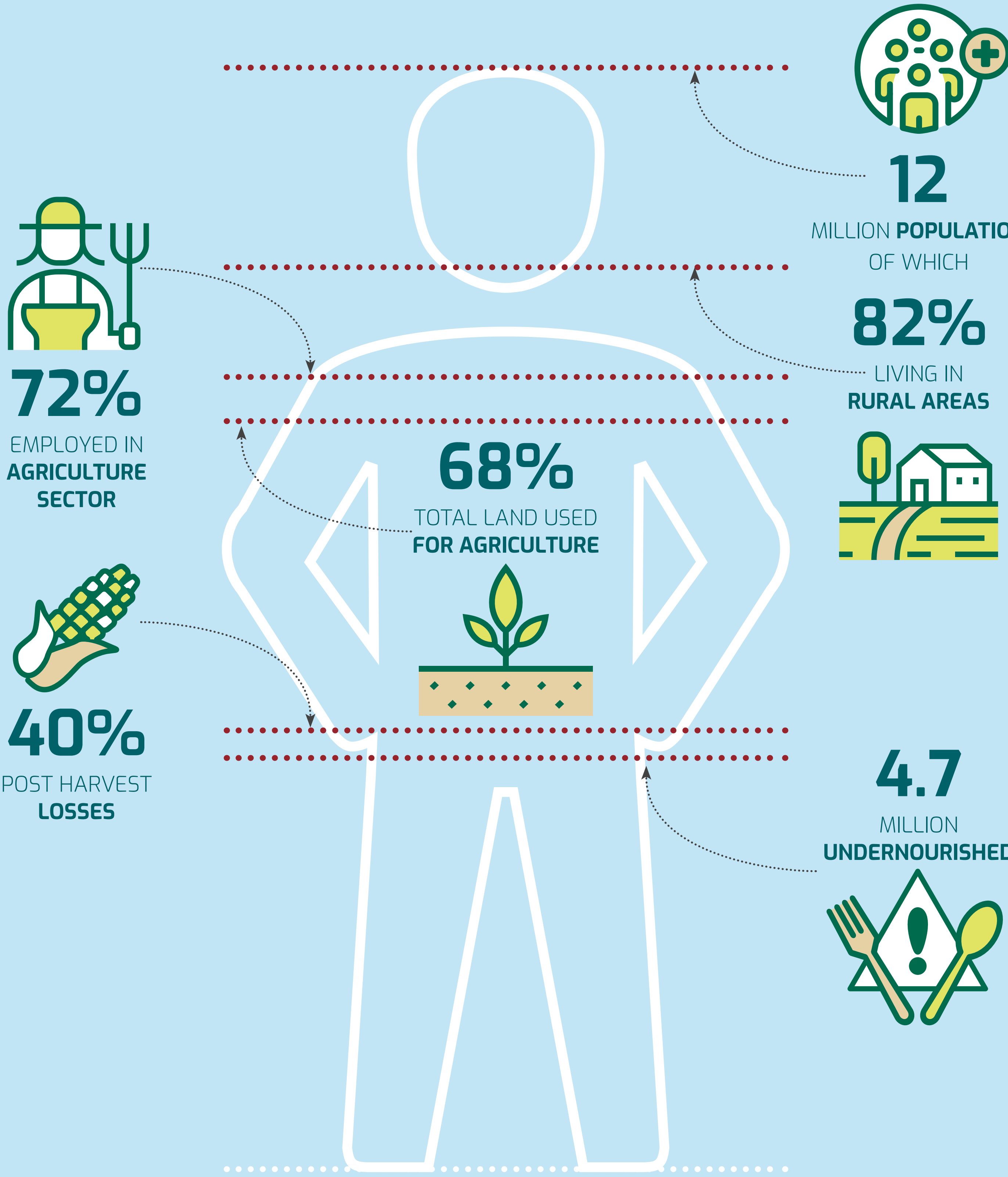
Additional challenges will arise from climate change impacts. According to the ND-GAIN Index, Rwanda is ranked 114th globally in terms of its vulnerability versus readiness to adapt to climate change.[12] Rwanda's agriculture is primarily rainfed, increasing its vulnerability to climate change, including more severe and frequent droughts and outbreaks of pests and diseases.[13] Compounding this issue are existing erosion conditions, poor soil fertility practices, and severely degraded land.[14] The impacts of climate change are expected to be multi-pronged, and some estimates suggest costs could rise additionally to 1% of GDP per year by 2030.[15]

Ultimately, as Rwanda continues to develop a more focused and ambitious policy framework to ensure food availability for its growing population, there are three primary interventions for consideration, outlined below:

- Increase domestic food production from the agriculture sector, either by expanding food production towards more marginal lands or by improving yields from its farming stock.
- Increase food imports.
- Reduce the amount of food that is lost and wasted, bringing it back into the food supply chain and improving the efficiency of food systems.

The solution will need to rely on a combination of these three options: yields, imports and less food loss and waste. Among these options, reducing food loss and waste offers the most untapped potential.

Rwanda Stats



1 Increasing Domestic Food Production From the Agriculture Sector

Rwanda could do this in two ways, although both present challenges:

Food supply could increase by expanding the agriculture frontier into unfarmed lands. However, over 68% of its territory is already farmed[16] and remaining lands are fragile ecosystems of low fertility and access that produce a myriad of environmental services including watersheds, biodiversity, and carbon sinks. Farm expansion would come at the expense of non-monetized environmental values and threaten the sustainability of food supply.

Food supply could increase by improving crop yields. While key agricultural yields have increased substantially, they are still lagging at about 40-50% of their productivity potential, suggesting opportunities for further growth. Yields reached a plateau in 2011 and have not been growing since then.[17] As Rwanda's agriculture sector is characterized as a low input, low output subsistence system, potential for yield gains remains through the use of high quality inputs, such as fertilizers and seeds, increased mechanization, as well as adopting small-scale, water efficient irrigation systems, all of which require investment at the farm level. Although increasing crop yields continues to be necessary and possible, the increased output will most certainly fall short of the food that is needed and will be highly variable with climate change.

2 Increasing Food Imports

Rwanda could import more food, and this will certainly be part of the solution to its food challenge going forward; however, this strategy faces limitations:

First, this would increase the import bill and affect the trade balance, the current account and currency reserves negatively. Domestic food prices could be distorted with implications for food security for both poor urban and rural households.

Second, Rwanda is a land locked country with insufficient trade infrastructure. Despite investments in logistics, trade costs remain stubbornly high. Today Rwanda is one of the most expensive places for a container to reach.[18]

Third, manifestations of food insecurity are likely to be localized. As rural connectivity issues remain, imported food may still not reach vulnerable populations. Most likely these households will be located in lagging regions and marginal areas of costly access making it expensive to deliver surplus food to them. It would be better to produce the additional food close to their locations.

3 Reducing the Amount of Food That is Lost and Wasted

Rwanda loses and wastes about 40% of its food supply.[19] Reducing food loss and waste would "increase" food yields from the stock of land and water already under farming. Even if food loss and waste were reduced only by half, it would help with food availability without additional environmental impacts on the food supply chain. Additional positive impacts include:

Reduced pressure on the import bill by increasing the availability of domestic food. Less imports would also increase food availability for other food-deficit regions, through decreased reliance on global food imports.

Benefits to remote and food-deficient households, through production-level interventions and avoided transportation costs.

A reduced carbon footprint of the food supply. While Rwanda's greenhouse gas emissions are negligible on a global scale, the country is a signatory to the Paris Agreement. Moreover, reducing emissions from food waste could open doors to some sources of climate mitigation-related financing.

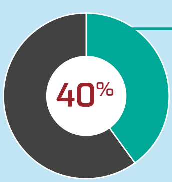
Commitment to Addressing Food Loss & Waste

Rwanda has made commitments to reduce food loss and waste at both the global level through the Sustainable Development Goals and their Nationally Determined Contribution under the Paris Climate Agreement, as well as regionally through the Malabo Declaration.* Specifically, it has committed to:

SDG 12.3	Malabo Declaration	NDC Policy Actions
By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses in farm production and along supply chains, including post-harvest losses.	Halve the current levels of post-harvest losses by the year 2025.	Adaptation policy actions: aspire to provide 100% of farmers with access to services for post-harvest treatment and storage of food crops; and post-harvest losses reduced to 1% by 2030 for maize, beans and rice.[20]

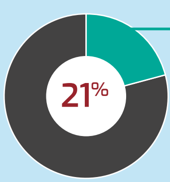
INDICATORS CALLING FOR GOVERNMENT ACTION[21]

Rwanda loses and wastes 40% of total production each year, which uses 21% of total land and contributes 16% of the country's greenhouse gas emissions. These losses represent 12% of Rwanda's annual GDP. At the same time, 19% of Rwandan households are food insecure, and the population is estimated to increase by 80% by 2050.



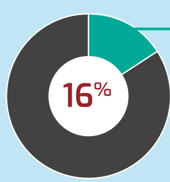
Volume

Rwanda loses 3 million tons of food per year



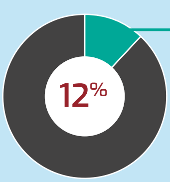
Land Use

FLW uses 564,400 ha. of land



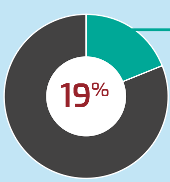
GHG emissions

FLW generates 1.2 mt CO_2 eq.



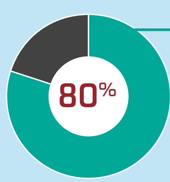
Economic Value

FLW costs Rwanda around 12% of its annual GDP2050



Food Insecurity

Prevalence of food insecurity



Population

Increase in population by 2050

Sources: USAID 2018; World Bank Open Data; WRI CAIT Climate Data Explorer; World Food Program, 2018; UN Population Prospects; and WB calculations

*Rwanda has also made significant commitments to ending hunger and undernutrition through its involvement in Compact2025, which aims to help countries develop country-owned and country-led strategies and investments to achieve these goals by 2025.

Key Commodities & Loss And Waste Hotspots

For Rwanda's diagnostic, a combination of staples and perishables is selected to illustrate potential policy impacts when reductions of losses and waste are implemented along the value chain. The two staples, maize and rice, are specifically mentioned in Rwanda's NDC and have therefore been prioritized. Tomatoes, a perishable, represent a large portion of perishables production for Rwanda and have experienced a growing demand from increased incomes and an expanding middle class within the country's population.

KEY STATS[22]

TABLE 1. Production, losses, and associated impacts for tomatoes, maize, and rice in Rwanda in 2017

	TOMATOES	MAIZE	RICE
Greenhouse Gases (GHG) Generated (tCO_2e)	**47,142**	**808,961**	**199,332**
Total Volume Produced	**97,400 tons**	**358,400 tons**	**109,000 tons**
Total Losses (Million Value Lost)	**49%** Total Losses (**$24.1** Million Value Lost)	**25%** Total Losses (**$37.5** Million Value Lost)	**18%** Total Losses (**$17.2** Million Value Lost)
Land Lost in Producing food loss and waste	**5,551 ha**	**74,362 ha**	**5,685 ha**

Sources: FAOSTAT 2017; APHLIS 2018; USAID 2018; WRI FLW Protocol FReSH FLW Value Calculator; and WB calculations

TOMATOES

Horticulture, especially for domestic consumption, is a priority growth area for the government.[23] Demand for tomatoes is rising due to economic growth and increased urbanization. Approximately 19 out of 30 districts in the country grow tomatoes, and eight of them grow an amount higher than 1,000 tons per year. Tomato production is mostly for the domestic market, with 20 to 30% used for home consumption and 70 to 80% sold domestically.[24] Currently there is no cold storage available at the farm or market stages of the value chain,[25] which causes the pulp temperature to be anywhere from 7-15°C higher than the ideal temperature at the farm, wholesale market, and retail market stages. This translates into a shelf life of 1-3 days instead of 1-3 weeks under ideal temperature conditions.[26]

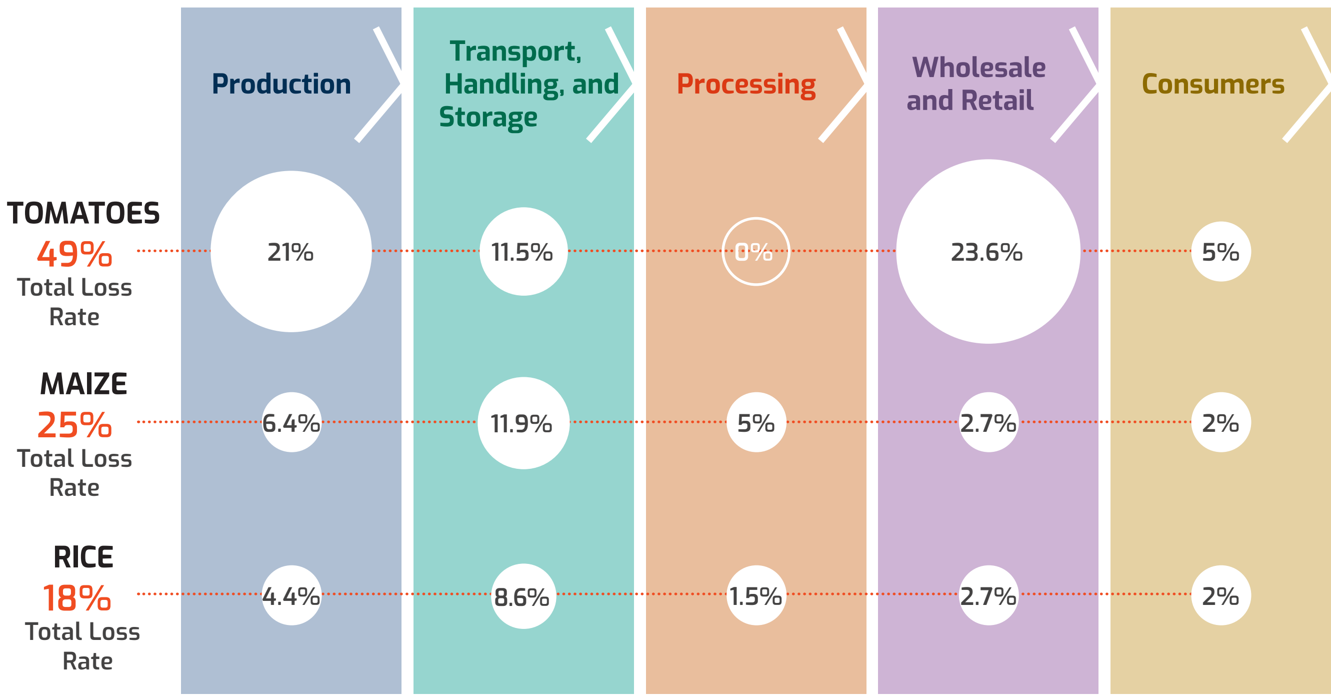
MAIZE

Rwanda has targeted maize as a priority sector due to the industry's potential to enhance GDP, expand exports, and promote food security.[27] The crop has become a major food security and income-generating crop for small-scale farmers. Rwanda's Crop Intensification Program (CIP) has led to over 65% of farmers now growing maize, both for household consumption and commercial sale to traders and millers.[28] Despite this boost in production, domestic supplies of maize have been insufficient in terms of quality standards required by the major buyers. This is driven largely by high moisture content and impurities, which contributes to aflatoxin contamination and therefore high levels of losses.

RICE

Rice is considered a priority crop for food security and poverty reduction in Rwanda.[29] Even though there has been a rapid rise in production in the past decade, Rwanda has been unable to meet its domestic growing demand for rice from national production, resulting in an increase in rice imports.[30] The government has set rice production as a priority, especially in the marshlands.[31] Losses in rice are largely due to inadequate handling and storage, resulting in the presence of aflatoxins.

FIGURE 3. Food loss and waste hotspots along the value chain in Rwanda (loss percentages occur at each stage)



Losses and waste occur at different locations along the value chain between the three commodities selected. Tomatoes have the largest total loss rate of 49%, followed by maize and rice, with 25% and 18%, respectively (Figure 3).[32] The total loss rates are calculated by applying the respective loss rates at each stage above to the volume that makes it past the prior stage.

Global Framework Highlights Impacts Of Food Loss & Waste Interventions

CONTEXT

Policymakers for Rwanda have competing policy goals. The country may be interested in:

- Reducing food loss and waste;
- Improving food security by increasing food consumption and reducing consumption costs;
- Improving farm welfare, that is, net farm incomes, to combat rural poverty;
- Reducing the stress on natural resources by reducing total farm production;
- Decreasing greenhouse gas (GHG) emissions; and
- Effectively managing net imports of food.

Given the demographic threat to and the extent of food insecurity within Rwanda's expanding population, improving food security is likely to be the driving policy goal followed by improving farmer welfare to reduce poverty. To guide policy, two types of analyses are necessary. First, how reductions in FLW contribute to the various policy goals, especially food security. Second, how interventions at various stages of the supply chain differ in terms of their effectiveness and costs and benefits.

The Global Framework, developed by the World Bank, focuses on the first type of analysis—how a reduction in FLW contributes to the policy goals.* A detailed analysis of costs, benefits and effectiveness of alternative interventions would be the next step towards a holistic FLW strategy. The Global Framework assesses the government's commitment of reducing food loss and waste by simulating the reduction in losses and waste rates by 50%. It then assesses how reductions at different stages of the supply chain compare in terms of their impact on outcomes of interest to support Rwanda's key priorities, which are improving food security and farmer welfare to reduce rural poverty.

The Framework takes initial farm sales and prices observed in the market and uses data on waste rates to infer the resulting prices and quantities at each subsequent stage of the supply chain down to the consumer level. The model is able to capture the case of a closed economy or reflect an open economy case with trade of pre-processed and processed products. The model derives GHG emission estimates based on emissions generated during production through the value chain as well as from waste generated at each stage. The different waste reduction scenarios presented in the information below reflect changes based on Rwanda's target of a 50% cut in waste rates at different points of the supply chain, and shows results for a series of policy priorities of interest, including farmer welfare (as measured by net profitability), food security (as measured by net consumption prices), trade (imports or exports), natural resource stress (as measured by farm production), GHG equivalent emissions, and total food waste. By jointly considering all stages of the supply

THE GLOBAL FRAMEWORK

is a model that captures the interconnected nature of food waste along the food supply chain, including at the stages of the farm (F); transportation, handling, and storage (T or THS); processor (P); retailer (R); and consumer (C). It allows for exports and imports between countries and shows the relationship between reductions in loss and waste levels at various stages of the value chain and associated impacts on prices, production, consumption, and priority policy objectives.

*Global Conceptual and Economic Framework on Food Loss and Waste, developed by the World Bank and partners, is forthcoming in 2020.

chain and assessing impacts on several policy priorities at the same time, the model is able to provide insights on the tradeoffs that result from different food waste reduction policies. This Framework compares situations of implementing food loss and waste reductions against a baseline of no interventions. In the coming years, the demand in Rwanda for food will increase. The model and accompanying analysis propose a more balanced approach to managing Rwanda's future food requirements where part of the food demand will be met by reduced food loss and waste.

A key assumption is the degree of openness of the food economy, and this will depend to some extent on the food commodity being considered. Looking at production, consumption, and trade patterns, it is clear that for perishables, Rwanda is effectively a dual economy—a closed economy for lagging, remote regions with poor infrastructure and connectivity, and an open economy with access to international markets, supporting infrastructure, and a rising middle class in urban areas. This may in fact require differentiated strategies for how to use food loss and waste reduction policies to address food security and farmer welfare. For staples, Rwanda is considered a small, open economy because staples tend to be transported better than perishables and Rwanda's staples import quantities have no significant impact on world prices. The model results suggest that in a small open economy, imports (or exports) play an important role in buffering farmers against potentially adverse indirect effects from price changes in response to food waste and loss reduction policies.

REDUCING LOSSES & WASTE OF TOMATOES

Rwanda is a small net importer of tomatoes and consumption is dominated by domestic production. Less than 5% of total consumption is imported, but this is likely to amount to a larger share of consumption in urban areas. Therefore, Rwanda can be viewed as a small country trader where reductions in losses and waste anywhere in the supply chain will not impact world prices and will therefore have no direct impact on domestic market prices at the levels of the supply chain where trade occurs. As Table 2 shows, when reductions in losses are made at the retail level, given the high initial rate of waste, food security improves

TABLE 2. Impact of reducing losses and waste of tomatoes at different points of the value chain (open economy model)

TOMATOES–OPEN ECONOMY MODEL

	Farmer Welfare	Food Security	Imports	Natural Resource Stress	GHG Emissions	Total Food Waste
50% reduction at production	↑ (Positive impact ≥ 5%)	↑ (Negligible impact < 1%)	↓ (Positive impact ≥ 5%)	↑ (Negative impact < 5%)	↓ (Positive impact ≥ 5%)	↓ (Positive impact ≥ 5%)
50% reduction at THS	↑ (Positive impact ≥ 5%)	↑ (Negligible impact < 1%)	↓ (Positive impact ≥ 5%)	↑ (Negative impact < 5%)	↓ (Positive impact < 5%)	↓ (Positive impact ≥ 5%)
50% reduction at retail	↓ (Negligible impact < 1%)	↑ (Positive impact ≥ 5%)	↓ (Positive impact ≥ 5%)	↑ (Negligible impact < 1%)	↓ (Positive impact < 5%)	↓ (Positive impact ≥ 5%)
50% reduction at consumer	↓ (Negligible impact < 1%)	↑ (Positive impact < 5%)	↓ (Positive impact ≥ 5%)	↑ (Negligible impact < 1%)	↓ (Negligible impact < 1%)	↓ (Positive impact < 5%)

LEGEND

- Positive impact < 5%
- Positive impact ≥ 5%
- Negative impact < 5%
- Negative impact ≥ 5%
- Negligible impact < 1%
- ↑↓ Direction of impact

significantly, compared to loss reductions at other stages of the value chain. A cut in rates of farm losses increases farm production and hence farmer welfare, but imports decline, reflecting reduced production in the rest of the world. This analysis shows that in the case of tomatoes for Rwanda, total domestic and rest of world production declines in this scenario. Any increase in the stress on domestic resources is thus likely to be partially offset by reduced production outside the country. With reductions in FLW at all stages, GHG emissions are reduced, with the greatest impact for reductions at the farm level. With reductions at any stage, total food waste always decreases, most substantially when reductions are made at the farm, THS, and retail stages.

For rural, marginalized areas of Rwanda, because of poor connectivity, a closed economy model may be more representative of economic conditions in the tomato (and perishables) sector. In a closed economy scenario, cutting losses at the farm level results in lower market prices, and hence lower production, which triggers a loss in producer welfare, as shown in Table 3. With these lower market prices and lower waste rates (and increase in available food), for interventions at every stage, food security improves more significantly in a closed economy compared to an open economy scenario. This highlights a case where there is a tradeoff between farmer and consumer welfare. For these farmers in rural areas who are net consumers of their production, reductions in losses significantly improves their food security. Finally, another difference between the open and closed economy scenarios for tomatoes in Rwanda is the impact on GHG emissions, which increase slightly in a closed economy scenario for decreases in rates of waste at the farm and THS levels.

TABLE 3. Impact of reducing losses and waste of tomatoes at different points of the value chain (closed economy model)

TOMATOES–CLOSED ECONOMY MODEL

	Farmer Welfare	Food Security	Natural Resource Stress	GHG Emissions	Total Food Waste
50% reduction at production	↓ (Negative impact ≥ 5%)	↑ (Positive impact ≥ 5%)	↓ (Positive impact < 5%)	↑ (Negative impact < 5%)	↓ (Positive impact ≥ 5%)
50% reduction at THS	↓ (Negative impact ≥ 5%)	↑ (Positive impact ≥ 5%)	↓ (Positive impact < 5%)	↑ (Negligible impact < 1%)	↓ (Positive impact ≥ 5%)
50% reduction at retail	↓ (Negligible impact < 1%)	↑ (Positive impact ≥ 5%)	↓ (Negligible impact < 1%)	↓ (Positive impact < 5%)	↓ (Positive impact ≥ 5%)
50% reduction at consumer	↓ (Negligible impact < 1%)	↑ (Positive impact < 5%)	↓ (Negligible impact < 1%)	↓ (Negligible impact < 1%)	↓ (Positive impact < 5%)

LEGEND

- Positive impact < 5%
- Positive impact ≥ 5%
- Negative impact < 5%
- Negative impact ≥ 5%
- Negligible impact < 1%
- ↑↓ Direction of impact

REDUCING LOSSES & WASTE OF MAIZE AND RICE

Similar to tomatoes, in the cases of maize and rice in a small open economy scenario, a reduction in farmer loss and waste rates leads to an increase in sales coupled with a small increase in farm production (see Tables 4 and 5 below), but any resource stress from the increase in domestic production is found to be partially offset by a large reduction in imports that reduces the rest of world production. Farmers see welfare improvement in the case of an open economy scenario with loss reductions at both the farm and THS levels. At the same time, consumers benefit from such a reduction through lower consumption prices.

A 50% cut in consumer waste leads to lower imports, with negligible impacts to farmer production and welfare, but improved food security at the household level with lower at-home consumption prices. A reduction in waste rates at any point of the supply chain triggers lower GHG emissions for the small open economy case for maize. Finally, total food waste declines significantly for both commodities.

In addition, for maize and rice in the open economy scenario, reducing food loss and waste increases farm production by at most by 1.5%, and therefore does not put significant added stress on natural resources that occurs through increasing farm output. For both commodities, reduction of food losses at the processor, retail, and consumer stages reduces farm production, implying slightly positive environmental impacts, while reduction of losses at the farm and THS levels slightly increases farm production.

TABLE 4. Impact of reducing losses and waste of maize at different points of the value chain (open economy model)

MAIZE–OPEN ECONOMY MODEL

	Farmer Welfare	Food Security	Imports	Natural Resource Stress	GHG Emissions	Total Food Waste
50% reduction at production	↑ (Positive impact < 5%)	↑ (Negligible impact < 1%)	↓ (Positive impact ≥ 5%)	↑ (Negligible impact < 1%)	↓ (Positive impact < 5%)	↓ (Positive impact ≥ 5%)
50% reduction at THS	↑ (Positive impact ≥ 5%)	↑ (Negligible impact < 1%)	↓ (Positive impact ≥ 5%)	↑ (Negative impact < 5%)	↓ (Positive impact < 5%)	↓ (Positive impact ≥ 5%)
50% reduction at processor	↓ (Negligible impact < 1%)	↑ (Positive impact < 5%)	↓ (Positive impact ≥ 5%)	↓ (Negligible impact < 1%)	↓ (Positive impact < 5%)	↓ (Positive impact ≥ 5%)
50% reduction at retail	↓ (Negligible impact < 1%)	↑ (Positive impact < 5%)	↓ (Positive impact ≥ 5%)	↓ (Negligible impact < 1%)	↓ (Positive impact < 5%)	↓ (Positive impact < 5%)
50% reduction at consumer	↓ (Negligible impact < 1%)	↑ (Positive impact < 5%)	↓ (Positive impact ≥ 5%)	↓ (Negligible impact < 1%)	↓ (Positive impact < 5%)	↓ (Positive impact < 5%)

LEGEND

- Positive impact < 5%
- Positive impact ≥ 5%
- Negative impact < 5%
- Negative impact ≥ 5%
- Negligible impact < 1%
- ↑↓ Direction of impact

TABLE 5. Impact of reducing losses and waste of rice at different points of the value chain (open economy model)

RICE–OPEN ECONOMY MODEL

	Farmer Welfare	Food Security	Imports	Natural Resource Stress	GHG Emissions	Total Food Waste
50% reduction at production	↑	↑	↓	↑	↓	↓
50% reduction at THS	↑	↑	↓	↑	↓	↓
50% reduction at processor	↓	↑	↓	↓	↓	↓
50% reduction at retail	↓	↑	↓	↓	↓	↓
50% reduction at consumer	↓	↑	↓	↓	↓	↓

LEGEND

- Positive impact < 5%
- Positive impact ≥ 5%
- Negative impact < 5%
- Negative impact ≥ 5%
- Negligible impact < 1%
- ↑↓ Direction of impact

Key Loss Drivers For Tomatoes, Maize, And Rice In Rwanda

Food loss and waste in Rwanda is in part a consequence of the perception of risk across the value chain by multiple actors. Farmers are hedging the risk of weather events, crop failures, and price volatility by overplanting—meaning that losses are likely a voluntary and rational outcome based on perceived risks. Lack of data and real-time information further compounds farmers' risk management challenges. For example, the lack of access to early warning systems, as well as labor and market conditions, means that instead of taking actions based on known or forecasted information, such as the cost of harvesting or market price, farmers are acting based on historical risk conditions which may be inappropriate or irrelevant for the current harvest season. Intermediaries often transport more than they intend to sell because of the risk that some will be lost along the route due to lacking or poor infrastructure. These and other market imperfections increase uncertainty and risks for both producers and consumers leading to the build-up of excess inventories or reserves as a hedge against a multitude of risks. These inventories may not be sold or consumed due to market conditions or spoilage, generating waste. Similarly, the private sector may view the investment to expand rural operations as risky, due to a mix of several factors, including an unfavorable policy environment or inadequate infrastructure to support operations.

This suggests an important role for risk-reducing policy interventions such as providing access to credit for farmers, entrepreneurs, and other relevant stakeholders across the value chain to improve availability of information and technologies such as cooling systems, refrigeration and improved storage facilities. Risk mitigation instruments, such as enabling policies or first loss guarantees, are going to be relevant to ensure private sector participation along the value chain. Figure 4 and the accompanying section below identify a list of relevant drivers of food loss and waste for the selected commodities across the value chain in Rwanda.[33]

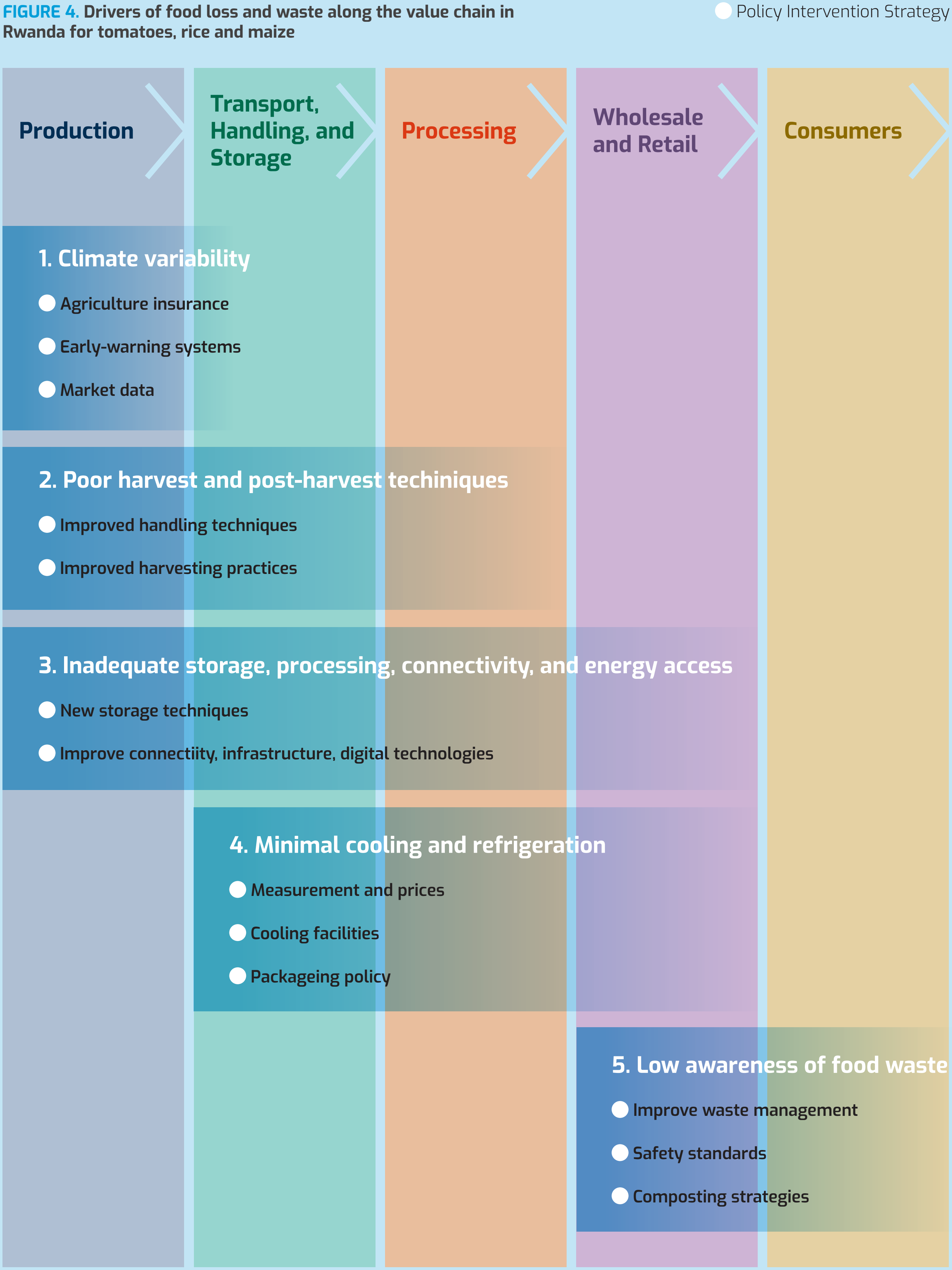
1. DATA, INFORMATION, & EARLY WARNING SYSTEMS FOR FARMERS

One of the biggest challenges around food and income security facing farmers is a lack of information and data to enable better farming decisions. Early warning systems can provide climate data that can help farmers make better planting and investment decisions. Using digital and/or mobile phone technology, farmers can access real-time market and pricing data, which can reduce decision-making under uncertainty. It can also help farmers adapt better to climate change. Improved access to data from early warning systems and better market information leads to more informed technical and business decisions, which can also help reduce losses. Without this knowledge it is difficult to create the appropriate strategies and policies that will enhance the agricultural value chain efficiency and minimize food loss.

2. IMPROVING KNOWLEDGE & CAPACITY SUPPORT

Governments and non-governmental agencies can play an important role in educating farmers and traders on improved post-harvesting practices, and on increasing awareness on food waste for urban centers and consumers. Building entrepreneurship in processing and storage solutions, including in cold storage, is equally critical for market development underpinning improved post-harvest management.

FIGURE 4. Drivers of food loss and waste along the value chain in Rwanda for tomatoes, rice and maize



3. STORAGE, TRANSPORT, & ROADS

Another significant challenge for Rwandan farmers is the lack of access to appropriate storage and processing facilities, adversely affecting the quality and food safety of produce. This is exacerbated by low rates of access to energy in rural areas, currently standing at 24%.[34] Road connectivity is low; however, the government is putting a lot of focus on this issue. For lagging and backroad regions, appropriate storage is critical to improve food security.

4. COOLING & REFRIGERATION ALONG VALUE CHAIN[35]

An appropriate cold chain at each step of the food supply chain is key to preserving food quality and preventing losses.[36] Rwanda today has limited cooling and refrigeration systems. However, the government is prioritizing cooling and released a cooling strategy in February 2019. The strategy underscores the importance of cooling for addressing food losses and increasing farmer incomes by scaling up cold chains at selected sites across the country. As of today, only 5% of firms in the food and agriculture sector have refrigerated trucks, while 9% have a cold room to store fresh produce.[37]

5. URBAN WASTE COLLECTION

As the population grows, with increased urbanization and improved living standards, there will be a need for a comprehensive waste management strategy for Rwanda. Today, with 18% of the population in urban areas, all collected waste goes to only one landfill in Kigali, which is dominated by 68% food waste,[38] contributing to potent methane emissions and air pollution in the city. Improved waste management from fork to landfill is necessary to ensure Rwanda's Paris Climate Agreement is met, urban centers are planning for increased capacity, and composting for food waste is viable.

InspiraFarms,

in partnership with the Ministry of Agriculture, is delivering a multi-unit refrigerated storage project which will benefit more than 100,000 smallholder farmers. The distribution of first mile refrigeration for small scale farmers can result in a reduction of up to 40% of on-farm crop losses.

Key Conclusions & Next Steps

For all open economy scenarios, Rwanda will not face a negative tradeoff between reducing losses and waste for any of the three commodities and achieving, at the same time, the six policy priorities of farmer welfare, food security, trade, natural resource stress, GHG emissions, and food waste. Although farm production, and therefore natural resource stress, increases by a small amount in a few scenarios, this could be compensated by a decline in imports, and associated natural resource stress, from the rest of the world. This implies that reductions in food loss and waste for all commodities at any stage in an open economy can help Rwanda achieve, at best, (or will not impede, at worst) its main development goals, demonstrating the positive spillover impacts for other policy priorities when reducing FLW in Rwanda.

Rwanda is effectively a dual economy for the case of perishables; a closed economy for lagging remote regions with poor infrastructure and connectivity, and an open, urban economy with access to international markets supporting a rising middle class. Rwanda will gradually shift to an open economy for perishables as the country continues to develop and rural connectivity improves. For those areas of the country that currently resemble a closed economy, a reduction in FLW would impact farmers negatively due to lower food prices from increased farm sales. In contrast, in an open economy, prices are determined by world markets, which protect farmers from adverse indirect effects due to changing prices. In both open and closed economies, food security always improves with reductions in FLW at any stage of the value chain.

This analysis suggests that for a small open economy like Rwanda, import substitution improves economic growth, food security and farmer welfare, while GHGs decline. Import substitution contributes to export diversification, a priority for Rwanda as a driver of growth.

The government of Rwanda seeks to transition to an export economy. This model suggests that for tomatoes, by cutting losses and waste in half, other things being equal, Rwanda can switch from a small importer to a significant exporter (ie. 10% of domestic production exported) of tomatoes.

In general, Rwanda will not face a negative tradeoff between reducing losses and waste of the selected commodities and achieving, at the same time, the government's policy priorities — demonstrating the positive spillover impacts when reducing FLW in Rwanda.

NEXT STEPS

Reducing food loss and waste is a promising strategy that can contribute to key policy goals of Rwanda. It makes more food available to consumers at a lower cost, improving food security. It improves farmer welfare (in a small open economy case), which is necessary to reduce rural poverty. It reduces GHG emissions in almost all scenarios. And more food in the system from less FLW allows the country to reduce its import bill, or to even become a net exporter as in the case of tomatoes. As shown, in the case of Rwanda, the resulting stress on natural resources from farming is partially offset by reductions in resource stress in other parts of the world.

The welfare impacts of reducing FLW depend on the stage of the supply chain where the intervention takes place. Given the current rates of waste for tomatoes in Rwanda, and likely perishables more broadly, the best strategy is to focus on reducing waste at the producer level, followed by reductions at THS level. For maize and rice, the dominant strategy is to reduce waste at the THS level, followed by the farm production level. Reducing waste by 50% would improve farmer welfare, food security, GHG emissions, and reduce the reliance on imports.

These results indicate that reducing FLW bears many potential benefits for Rwanda and identifies the tradeoffs between competing policy goals implied by reductions in waste at different stages of the supply chain. Going forward, the design of Rwanda's FLW strategy should be based on a careful analysis of alternative interventions, their associated costs, benefits, feasibility of implementation, and effectiveness in reducing FLW, as well as the public and private investments necessary for its implementation. This could also mean conducting an analysis across a broader range of commodities as per Rwanda's interest.

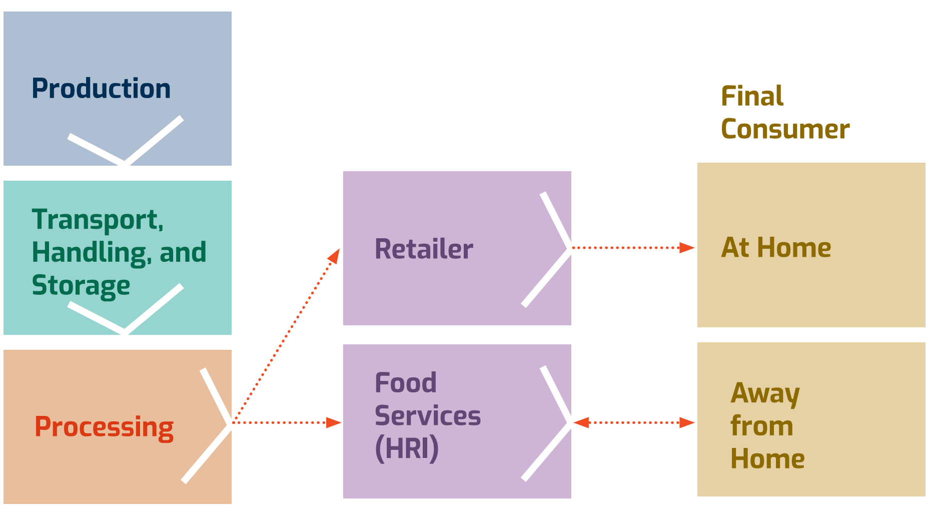
Technical Annex: Global Framework

This technical annex summarizes the analytical structure of the Global Framework. Detail is provided on the modeling approach and key assumptions, describe the calibration of the model to the status quo, outline how the model generates simulation results for the different policy scenarios, and consider impacts on total resource stress in the case of an open economy.

MODEL STRUCTURE

The length, structure, and distribution of food loss and waste rates along the food supply chain of a country have important implications for food loss and waste reduction policies.[39] The stylized model under the Global Framework captures six distinct stages in the food supply chain (see Figure 1). These include post-harvest losses at the farm level, as well as food loss and waste generated in transportation, handling and storage (THS), processing, retailing, hotels, restaurants and institutions (HRI), and at-home vs. away-from home consumption. The model highlights that interventions at one level of the chain (such as a reduction in waste rates at the retail level through improved food storage systems) can impact market prices which in turn leads to indirect effects on other stages of the supply chain. Capturing these indirect effects is critical in providing a holistic and realistic assessment of food waste reduction policies.

Figure 1: Stages of the Vertical Food Supply Chain



The model shows that the direction and magnitude of the indirect effects depends on the interaction of supply and demand elasticities at each level of the chain. The price elasticity of consumer demand in particular plays a key role in determining the effects of policy interventions at different stages of the supply chain. Assumptions regarding international trade are also shown to be critical. The model therefore considers three trade scenarios: a closed economy, a small open economy (in which the country exerts little influence on world prices) and a large open economy. For the latter, the elasticity of export supply (import demand) facing the country[40] versus the elasticity of import demand (export supply) of the country[41] are found to have important implications for the changes in producer welfare after an exogenous reduction in waste rates at the farm or THS level.

STATUS QUO: CALIBRATION

The model takes as given the initial farm sales (q_F) and prices (p_F) for a given country and commodity context, and uses data on waste rates (α) to infer the resulting prices and quantities at each subsequent stage of the supply chain down to the consumer level. Figure 2 illustrates the transmission of quantities along the supply chain. For example, the quantity of food reaching THS is given by $q_{TS} = (1 - \alpha_F)q_F$, i.e. the quantity of farm sales adjusted for post-harvest losses. The model also allows for trade of pre-processed (NTR_P) and processed (NTR_P) food and takes into account the retail share which determines the split of food passing through retail versus HRI.

Figure 2: Transmission of Food Along the Supply Chain

$$q_F$$
$$\downarrow$$
$$q_{TS} = (1 - \alpha_F)q_F$$
$$\downarrow$$
$$q_T = (1 - \alpha_T)q_{TS}$$
$$\downarrow$$
$$q_{PS} = q_T - NTR_P$$
$$\downarrow$$
$$q_P = (1 - \alpha_P)q_{PS} - NTR_R$$
$$\swarrow \qquad \searrow$$
$$q_{HS} = (1 - s)q_p \qquad\qquad q_{RS} = sq_p$$
$$\downarrow \qquad\qquad\qquad\qquad \downarrow$$
$$q_H = (1 - \alpha_H)q_{HS} \qquad\qquad q_R = (1 - \alpha_R)q_{RS}$$
$$\searrow \qquad \swarrow$$
$$\boxed{\begin{array}{l} q_C = (1 - \alpha_C)q_R \\ q_A = (1 - \alpha_A)q_H \end{array}}$$

Downstream prices are derived in a similar way, taking waste rates, disposition costs and intermediary margins into account. To capture the effect of policy interventions on GHG emissions, the model calculates the amount of total emissions from both total production and consumption (including the amount wasted), and from the disposition of waste itself.

In order to be able to run policy simulations, the model assumes functional forms for trade, farm supply and consumer demand. It also assumes that trade curves are linear while farm supply and consumer demand are of the Constant Elasticity of Substitution (CES) form. The model then calibrates these functional forms to market data for the given country and commodity setting.

POLICY SCENARIOS: SIMULATION

Margins, food loss and waste rates, disposition costs and taxes are considered exogenous in this setup and can be shocked to reflect alternative policy interventions. In line with Rwanda's commitment to reducing food waste by 50%, the main intervention of interest are policies which halve the exogenous rate of waste **(α)** at different parts of the supply chain. For each considered scenario, the Global Framework endogenously determines the resulting farm price and quantity which ensure market clearing at all stages of the supply chain and balance trade between the considered country and the rest of the world.

The model then calculates impacts on a series of outcome measures of interest including food security (as measured by effective consumption prices which represent retail prices the consumer faces adjusted for consumer waste), farmer welfare, total waste, imports and GHGEs. Crucially, by jointly taking into account all stages of the supply chain and assessing impacts on several outcome measures at the same time, the model is able to speak to the tradeoffs that result from different food waste reduction policies.

OPEN ECONOMY SCENARIO, FARMER WELFARE, AND GLOBAL RESOURCE STRESS

Under the Global Framework, the small open economy case provides a buffer against losses in producer welfare (which occur in the case of a closed economy) but increases local resource stress (as measured in the amount of farm production) in response to a reduction in farm level food loss and waste rates. However, the increase in local resource stress is partially offset by a reduction in resource stress in the rest of the world.

The effect on producer welfare is driven by the fact that a small country cannot affect world prices at the stage of the supply chain where trade occurs, which partially insulates the domestic agents against indirect effects from price changes. To illustrate the effect on the total world resource stress, consider the case of a small country importer. A reduction in farmer loss rates in this case leads to an increase in farm production (and hence local resource stress) but a reduction in imports. Since a decrease in local imports must result in an equal and offsetting reduction in exports by the rest of the world, production in the rest of the world must also decrease, which partially offsets the local resource stress. The degree to which the reduction in imports offsets the effect on total resource stress depends on relative supply/demand elasticities in the rest of the world, and on relative loss and waste rates between the local country and the rest of the world at the farm and pre-processed level.

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