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Nigeria

Food Smart Country Diagnostic

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Nigeria 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 (GHG) 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.**

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A "FOOD SMART" NIGERIA

Nigeria is ranked 96 out of 113 on the Global Food Security Index (2018). Indications are that food security will worsen as the nation's population doubles from 201 million today to around 400 million by 2050, and its urbanized population increases to reach approximately 70% by 2050. In addition, over 12% of Nigerians are undernourished.[1] Yet each year, Nigeria loses and wastes 40% of its total food production, equal to 31% of its total land use and producing 5% of the country's GHG emissions.

This study of Nigeria FLW analyzes the potential policy impacts of reducing food loss and waste (FLW) along the value chain for three strategically selected commodities: maize, tomatoes, and catfish. The study takes into account the differences between food-producing regions of the north (a poor, rural, closed economy challenged by civil conflict) and largely food-consuming regions of the south (an open economy with an increasingly urbanized population).

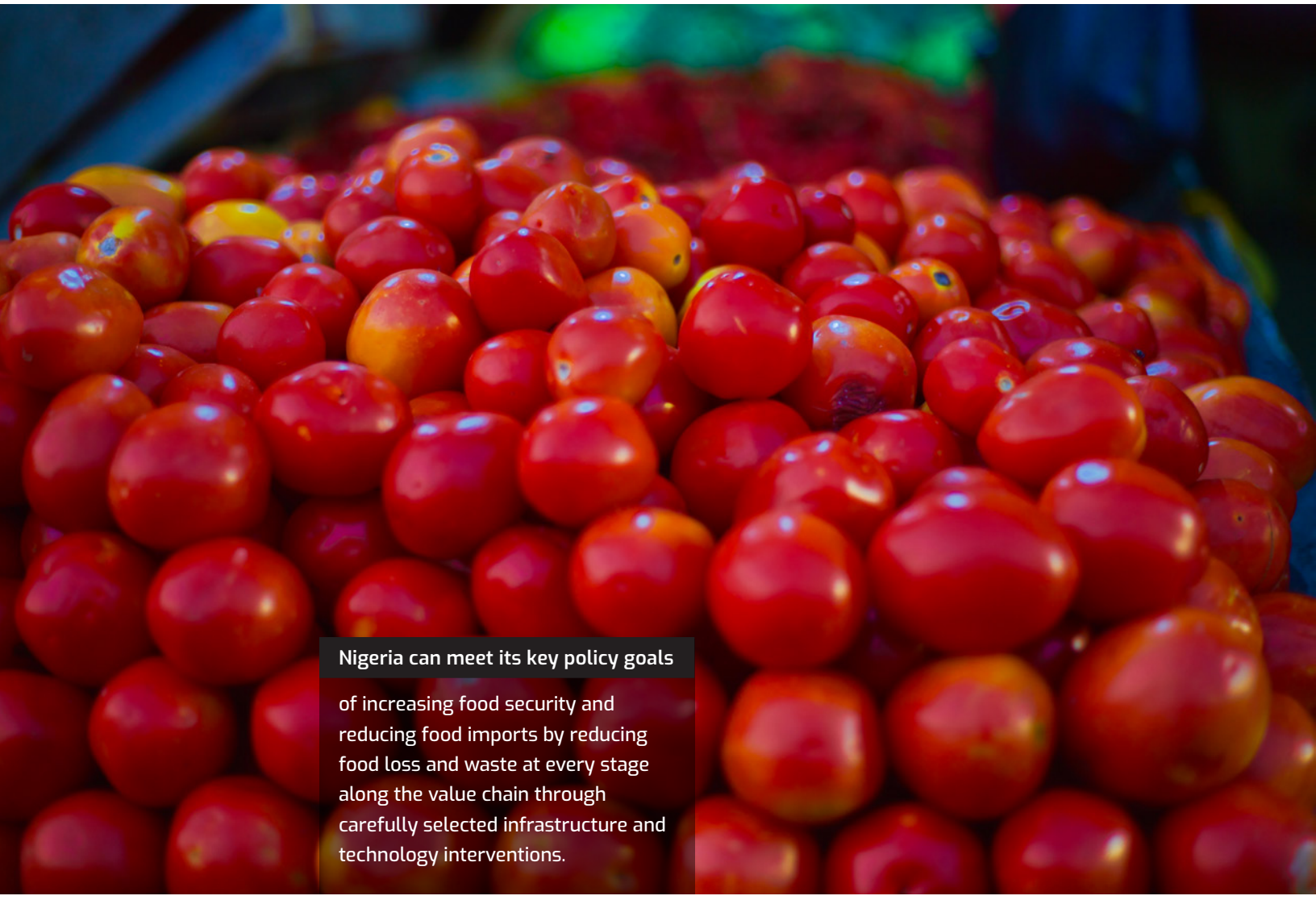
The study found that reducing FLW for all three commodities will allow Nigeria to address key policy priorities, chief among them improving food security. Other priorities include

*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 4

improving rural, low-income farmer welfare; meeting Nigeria's international commitments to reduce GHG emissions produced by food waste; increasing food exports; and reducing food imports while satisfying the nation's large urbanized population's shift towards a more diversified diet.

Tactics that hold promise include 1) Real-time, actionable information delivered to farmers on weather, climate change-related effects, labor data, and market conditions so farmers can protect their crops from damage and their livelihoods from price volatility; 2) Improved storage and handling techniques during transportation and on farms, particularly through innovative models of organization, reshaping cooperatives for a greater impact; 3) Improvements to Nigeria's transportation routes; 4) Improved refrigeration at each step of the food supply chain; and 5) Improved urban waste management — from homes to landfills. The study recommends that specific food loss and waste reduction strategies be adopted after a careful cost-benefit analysis, and suggests the possible need to create social safety nets for farmers to protect them from any price decreases that result from implementing FLW-reduction tactics.



Nigeria can meet its key policy goals

of increasing food security and reducing food imports by reducing food loss and waste at every stage along the value chain through carefully selected infrastructure and technology interventions.

Nigeria's Challenge: Feeding its Booming Population Inclusively

The largest economy and most populous country in Africa, Nigeria's growth has primarily centered around oil revenue. With large regional differences, poverty in Nigeria remains widespread, standing at 39% below the national poverty line in 2016, or around 74 million people. Most of the country's poor live in the north, where the poverty rate is five times higher than in the south, and low connectivity, market fragmentation, and conflict hinder growth.[2] Characterized by small-scale, low productivity, rain-fed subsistence farming, agriculture remains the most important source of employment for the population and the poor, and accounts for 90% of rural livelihoods.[3] Economic activities are heavily concentrated in the south of the country, where educational levels, basic services, and higher productivity jobs are located.

Demographic shifts, spurred by a high growth rate and young population, will further stress the domestic food system, which struggles to adequately and nutritiously feed its growing population. Nigeria is set to see its population double from 201 million today to around 400 million by 2050.[4] Ranked 96 out of 113 countries on the Global Food Security Index in 2018, Nigeria had close to 25 million undernourished in 2018.[5,6] The situation is more dire in conflict zones, where 70% of households were food insecure in each conflict zone in 2016.[7] Coupled with the high population growth rate and rising food insecurity is another exacerbating trend for the food system: rapid urbanization. Nigeria is already more urbanized than the rest of Sub-Saharan Africa (48% vs. 38%, respectively[8]), and its urbanization rate remains one of the highest in the world at 4.2% in 2018.[9] It's estimated that the percentage of urban dwellers will grow to around 70% by 2050, or 280 million people.[10] With this transition also comes rising incomes and shifting diets demanding higher value, more nutritious foods. This will require an update to the country's infrastructure, which is currently built to support staples and starchy roots and tubers, namely maize, rice, cassava, and yams. In an environment where foodborne diseases are already very costly for Nigeria, estimated at US$6 billion in 2016, the increase in consumption of perishables and proteins will further prompt food safety concerns.[11]

Nigeria must transform its food system to be more efficient and inclusive to ensure food and nutrition security as the population doubles over the next 30 years. An equally critical priority for Nigeria is poverty reduction, especially in remote and conflict-prone regions, where agriculture is the main source of employment. A more efficient food system will not only alleviate some of the existing shortfalls in terms of farmer incomes and food security, but it also will encourage the agri-food sector to play a larger role in diversifying the economy through reduced dependency on the volatile oil sector, offering import substitution, and starting the pathway towards becoming a regional and global agri-food exporter. There are multiple ways in which Nigeria could increase the efficiency of its food system, but a reduction in food loss and waste (FLW) holds the most potential for an immediate impact on achieving the country's priorities.

1. **Productivity of the agriculture sector is lagging and could take many years to reach its full potential.** Increases in production levels of most major crops in Nigeria masks the reality of stagnant or falling yields counteracted by increased land conversion and area under cultivation. The historical reliance on the oil sector has played a significant role in eroding the competitiveness of the agriculture sector due to insufficient

investment in the sector. This is evident in the fact that the country's investment in research, as a share of agricultural GDP, fell from an already low 0.39% in 2008 to 0.22% in 2014 – compared to Ghana's share of 0.99% and South Africa's 2.79%. Smallholder farmers are operating with weak research and extension services, limited use of improved genetics and fertilizer, and low levels of mechanization and irrigation.[12] Deploying these improved technologies will require significant investment and time before farmers see any benefit.

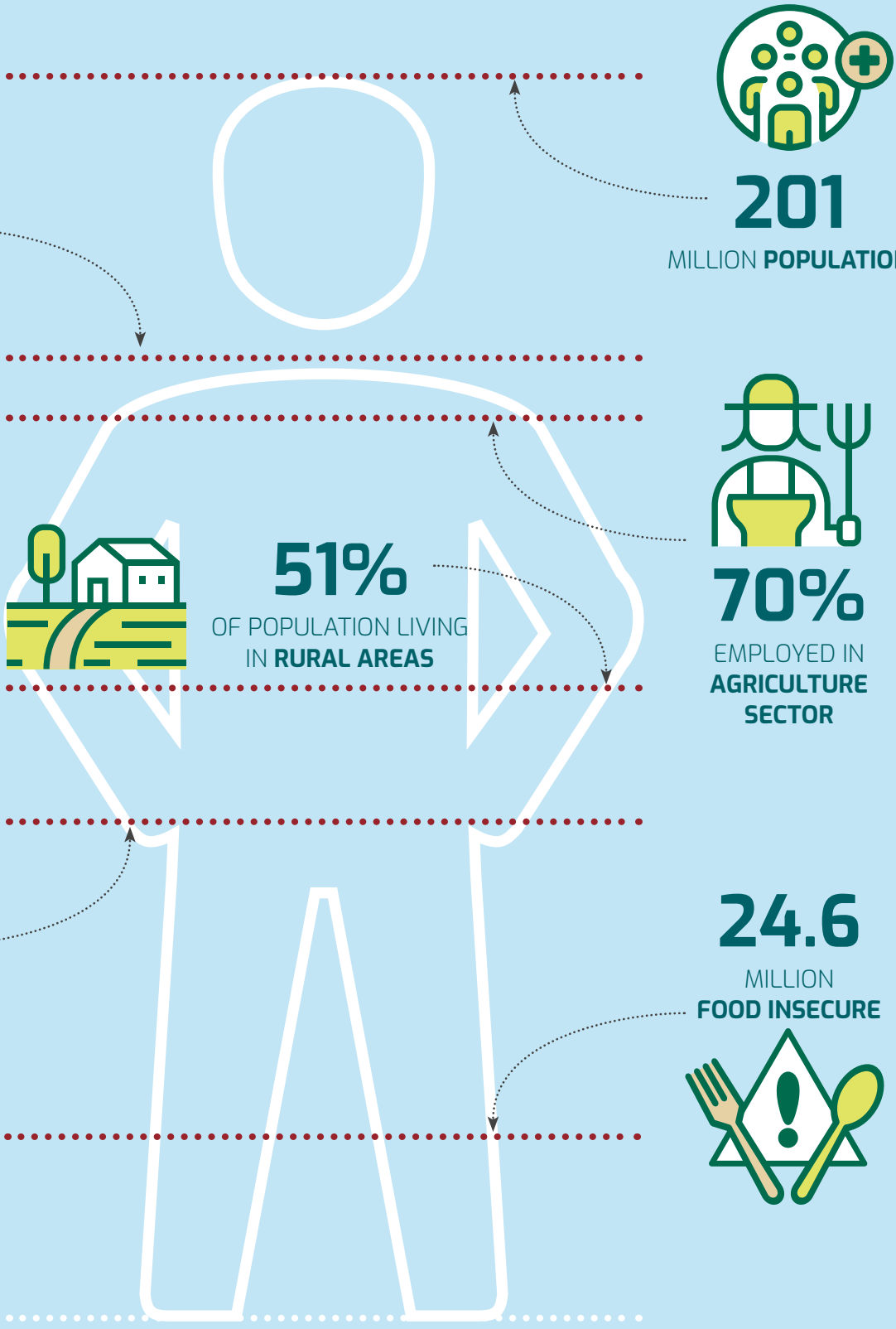
Furthermore, Nigeria cannot afford to continue to expand its agricultural footprint, which at best is on marginal land with low yields, and at worst can lead to loss of life. At present, in most parts of the country, the land frontier has already been exhausted. Any expansion that is taking place currently is increasingly on marginal land where yields are lower.[13] In the south, crop land expansion can only come at the expense of the last remaining dense forest areas; while in the north, crop production is in serious competition – sometimes to the point of open conflict – with pastoral livestock systems. In 2018, the violence between nomadic cow herders, migrating south due to climate-induced degradation of pasture and increasing violence in the far north, and crop farmers in Nigeria's Middle Belt was six time deadlier than that of the insurgency group Boko Haram, claiming 1,949 lives, nearly double the 2017 figure.[14] This conflict further hinders potential gains in productivity, leaving the sector with a weakened outlook.

CONFLICT AND THE AGRICULTURE SECTOR

Home to over 300 ethnicities across six geopolitical regions, Nigeria has struggled to achieve social cohesion. Widespread conflict still plagues parts of the country, especially in the North East, Middle Belt, and the Niger Delta. The North East and Middle Belt conflicts most heavily impact the agriculture sector given the large rural employment and livelihood dependence. The Boko Haram insurgency and the military operations to counter it have killed more than 20,000 people and displaced nearly 2.4 million people in the North East since 2009. Farmers in the North East state of Borno reported reductions in production of a variety of crops ranging between below 50-100% when comparing harvests during conflict to pre-conflict output. Lower availability of labor, for fear of being attacked on farm or road, in addition to increased prices, lower availability, and farther distances traveled to obtain fertilizer, herbicides and improved seeds are primary causes for the reduced output. This also negatively affects downstream actors, such as processors, who are reliant upon the raw materials to continue operating.[19] In the Middle Belt, clashes between nomadic herders and sedentary farmers have been increasing because of competition over land resources.[20]

Climate-induced degradation of pastures, coupled with violence in the north, has pushed herders further south into crop farming areas. Around 300,000 people were displaced in 2018 from this decades-old conflict.[21] With smallholder farmers already operating at a disadvantage from reduced technology adoption, weak research and extension services, and little mechanization, these conflicts further exacerbate productivity challenges. Reductions in losses on or near the farm hold the potential to lessen some stress affecting smallholder farmers by making more food available where it is most needed, thereby increasing food security where the need is greatest.

Nigeria Stats



2. **Insufficient infrastructure reduces the ability of imports to reach food insecure rural regions.** In an effort to stimulate domestic agricultural output and control its food supply, in 2015 the government put in place a policy restricting access to foreign exchange for some food imports.[15] However, increased production still cannot meet current food supply demand, and food and beverage imports still represented a sizeable portion of Nigeria's import bill, around 14% in 2017.[16] Nearly half of imports are primary food products that, with increased productivity and efficiency in the value chain, smallholder farmers could potentially replace. Moreover, if Nigeria were to import more food to feed its population, the country lacks sufficient infrastructure to ensure that those who need it the most have access. Rural connectivity is low, and without adequate storage and cooling technologies in place, perishables cannot reach remote, lagging locations where food insecurity and malnutrition are the highest. Subsequently, most imported foods are consumed in urban areas, where food insecurity is less prevalent. Compared to peers with lower per capita gross national income (GNI), such as Ghana and India, Nigeria's road density is low. This results in approximately 75% of Nigeria's rural population without access to an all-season road network. Farmers already feel the impact of inadequate rural infrastructure, which manifests itself in transportation costs reducing farmgate prices and accounting for about 70% of fertilizer acquisition cost.[17]

CLIMATE CHANGE IMPACTS

Global climate models, coupled with crop production models, forecast a range of lower yields in the West Africa region and Nigeria by 2050 as a result of climate change, with more severe yield reductions occurring in the period between 2030 and 2050. Higher temperatures will likely be the primary cause of this, due to increased evapotranspiration.[22] As a top ten country vulnerable to climate change, Nigeria is predicted to experience not only an increase in average temperature, but also more variability in rainfall, rising sea levels, and an increase in extreme weather events. Many of the climate change impacts are expected to hit hardest in the north, where the population is heavily reliant upon agriculture and livestock for employment and food security. For coastal settlements, towns, and cities, such as Lagos, a 0.2 meter rise in sea level would inundate 3,400 km of Nigerian coast-land, and a 1.0 meter rise would cover 18,400 km.[23] Indirect impacts from climate change on the agriculture sector may also include induced migration, aggravated existing natural resource conflicts, and shifting distribution of pests and diseases.[24] Furthermore, as one of the most disaster-prone countries in Africa, Nigeria is extremely vulnerable to droughts, floods, landslides, gully erosion, and wind storms. In September and October of 2012, floods affected 32 states, close to 6 million people were displaced, and the estimated damages and losses totaled USD 16 billion.[25] Climate change will undoubtedly further stress the Nigerian agriculture sector and food supply, exacerbating the existing food insecurity challenges and elevating the need to increase efficiency within the sector.

3. **Reducing food loss and waste provides immediate impact for the poorest and most vulnerable, maximizing output from land and natural resources already under production.** A reduction in losses and waste, which currently stand at around 40% of all food produced,[18] increases food availability in regions where it's grown and most needed and can enable the ability to diversify diets to a more nutritious one. Nigeria would effectively increase "productivity" without a tradeoff between other policy objectives, such as land conversion. Lowering losses on and near the farm would also provide a buffer against the impacts of climate change.

NIGERIA'S URBAN FOOD SYSTEMS

Nigeria's urban population has grown in the range of 4-6% per year since the early 1970s, with Lagos the largest urban center with around 14 million residents in 2019.[26,27] Projections estimate that the city will continue to grow at a similar average rate of 3.5% per year to 2030, reaching a population of over 20 million, roughly the present size of Mali or Burkina Faso.[28] Currently, local food production near Lagos meets only 10% of the local demand, with the remaining supply fulfilled form elsewhere domestically as well as international imports. Traditional markets are the primary channel for food sales in Nigeria, for both domestic and imported, as well as raw and processed, foods. In fact, more than 90% of domestic staple foodstuffs, and more than 90% of imported food products, are sold at traditional markets. Meanwhile, food sales through supermarkets only account for around 1% of total sales, and 80% of their food stocking is purchased from importers and wholesalers located in traditional open markets.[29] Due to inadequate infrastructure, legal and bureaucratic restrictions, and customs challenges, the transportation of produce takes a significant amount of time and money to reach urban centers from rural Nigeria. The majority of this transport is done in open, non-refrigerated trucks, and in 2014 it was estimated that 50% of losses of plantains and bananas in Nigeria occur during transportation from the farm to market places, and account for 2.5% to 6.6% of wholesalers' potential total revenue.[30] With a booming urban population, in addition to increasing incomes and shifting diets, Lagos and other urban centers are set to see a rise in the demand for perishables and protein. Without addressing losses and waste along the value chain, this rise in demand will likely increase losses and waste for Nigeria.

FOOD SAFETY

Nigeria faces serious food safety issues in its food supply and a particularly high burden of foodborne disease. In the 2010s the country experienced tens of millions of cases of foodborne illness and tens of thousands of related deaths, according to unpublished WHO estimates. Associated productivity losses are also significant, on the order of US$ 6 billion in 2016, which is high in relative terms compared to peers, controlling for population and average national income.[31] Foodborne disease in Nigeria is heavily, if not overwhelmingly, attributable to animal source foods, including seafood, which is consumed at a high rate and will continue to grow as incomes rise. Alongside meat and fish, street foods and vegetables have both been singled out as major food safety concerns in Nigeria.[32] Out-of-home eating, and specifically reliance on informal food vendors, is ubiquitous in urban Nigeria.[33] Food safety hazards and risk factors vary by commodity and supply chain; however, one overarching food safety risk factor in Nigeria is the predominance of the informal and traditional sectors in food production, processing, and marketing—sectors that generally lack the infrastructure, know-how, capacity, and incentives to handle food safety.[34] The rejection of food from markets on the basis of food safety concerns can be a major driver of food loss and waste, and improvements in food safety risk management may be an important means of achieving reductions in losses and waste, the interventions for which are often symbiotic with food safety objectives. As diets in urban areas continue to shift towards increased perishables and protein consumption, which carry the highest risks of foodborne disease, Nigeria will need to tackle its food safety challenge in order to achieve a nutritious, sustainable food system. Furthermore, with a national priority to become a global agri-food exporter, a focus on improving the safety and quality of food supply chains from cultivation through export will be critical to reduce import rejections and establish a global presence.

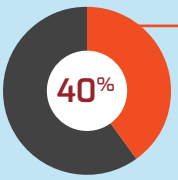
COMMITMENT TO ADDRESSING FOOD LOSS AND WASTE

Nigeria 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 along production and supply chains, including post-harvest losses.	Halve the current levels of post-harvest losses by the year 2025.	Mitigation policy actions: transitioning into climate smart agriculture as part of their Vision 2020.

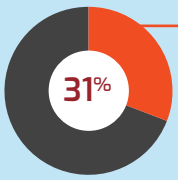
INDICATORS TRIGGERING GOVERNMENT ACTION ON LOSSES AND WASTE REDUCTION

Nigeria loses and wastes 40% of total production each year[35], which uses 31% of total land and contributes 5% of the country's greenhouse gas emissions. These losses represent 9.1% of Nigeria's GDP. At the same time, 44% of Nigerians are food insecure, and the population is estimated to increase by more than 50% in 2050.



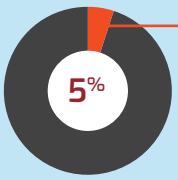
Volume

Nigeria loses 76.9 million metric tonnes of food per year



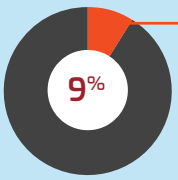
Land Use

FLW uses 283 200 sq. km of land



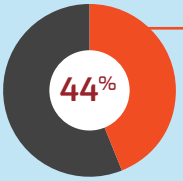
GHG emissions

FLW generates 25.6 mt CO2 eq



Economic Value

FLW costs Nigeria around 9.1% of GDP annually



Food Insecurity

Prevalence of food insecurity

Population Increase

Increase in population by 2050

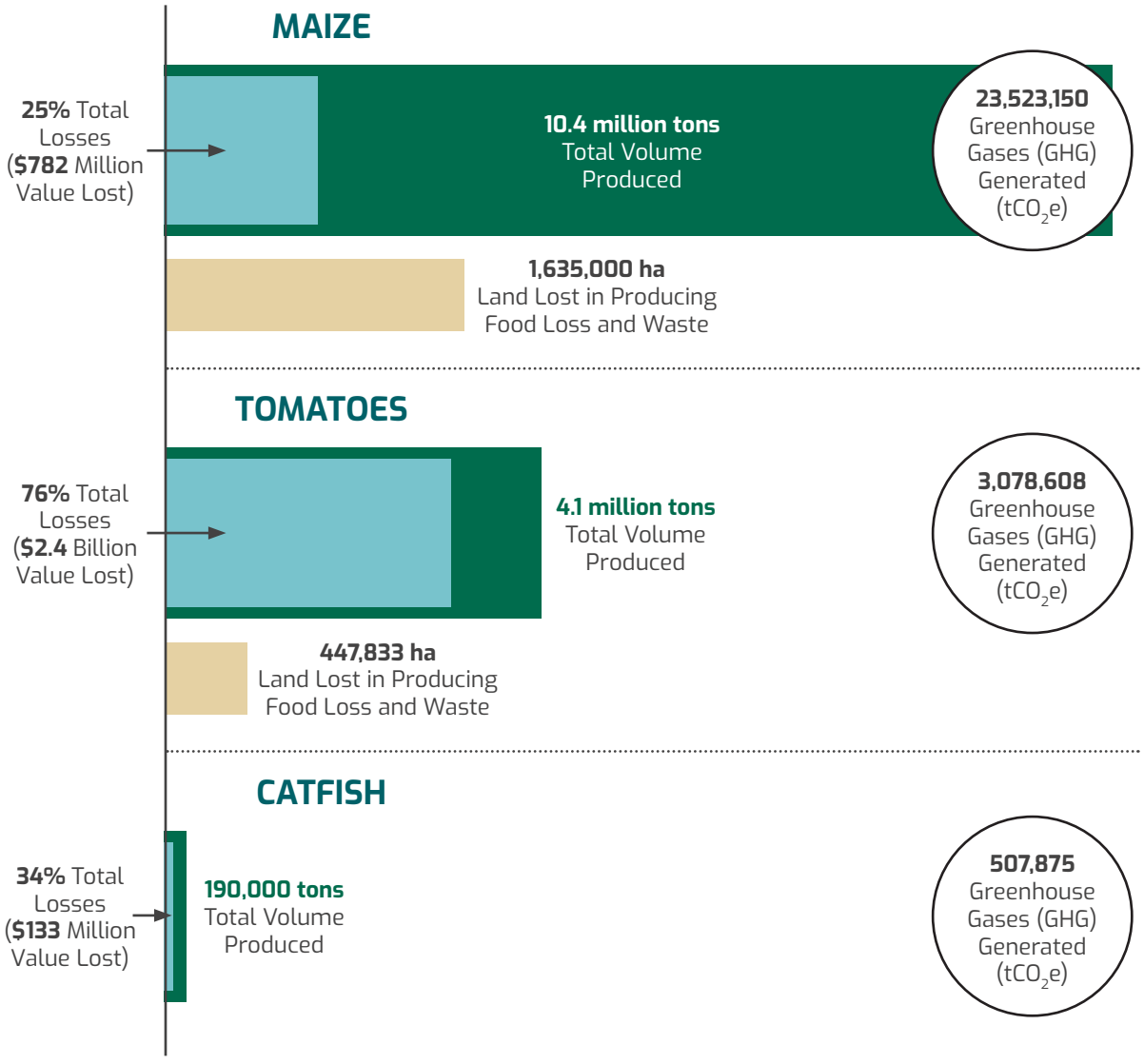
Sources: FAOSTAT 2017, The Herald, Africacheck[36], World Bank Open Data, UN population prospects, WRI CAIT Climate Data Explorer, FAO et al (2019) and WB calculations

Key Commodities & Loss and Waste Hotspots

For Nigeria'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. Maize is the dominant staple produced in Nigeria and remains a critical contributor to caloric sufficiency and food security in the country. Tomatoes are the most widely grown perishable in the country, offer critical micronutrients, and have experienced a growing demand from increased incomes and an expanding middle class within the country's population. While fish is a widely consumed protein source in Nigeria, current production cannot meet demand, and Nigeria is a significant importer of fish globally. Aquaculture within the country holds high potential for meeting some of this increasing demand for fish in the coming decades as diets continue to shift and incomes rise.

KEY STATS[36]

TABLE 1. Production, losses, and associated impacts for maize, tomatoes, and aquaculture catfish in Nigeria in 2017



Sources: FAOSTAT 2017; FAOSTAT 2011; Gromko and Abdurasulova 2019; Adelaja, Kamaruddin, and Chiat 2018; WRI FLW Protocol FReSH FLW Value Calculator; Henriksson 2015; and WB calculations

MAIZE

Maize is a valuable staple crop in Nigeria, geographically dispersed across the country. One of the largest African maize producers, Nigeria produces over 10 million tonnes annually. Maize is vastly used for human consumption, but also comprises between 50-70% of livestock feed. Considered a food security crop, maize, along with other grains, accounts for about 70% of the total caloric intake in most African countries.[38] Per capita consumption of maize in Nigeria totaled 35 kg in 2017.[39] Since most maize crops in Nigeria are rainfed, it is highly vulnerable to climate variability, especially in the north, where impacts are expected to be more extreme.

TOMATOES

Tomatoes are important for the Nigerian economy both in terms of production, mostly by small-scale farmers, and consumption, as the most commonly used vegetable in regular diets.[40] Nigeria is the 2nd largest producer of fresh tomatoes in Africa and 14th largest in the world. Over the last decade, production of fresh tomatoes grew significantly, facilitated by an increase in the harvested area from 265,000 ha to 668,292 ha in 2016.[41] At the same time, Nigeria is the 3rd largest importer of tomato paste in Africa and 13th in the world.[42] Nigeria also imports significant volumes of tomatoes due to severe seasonal variation. For example, between March and July there is nearly zero local production, with overproduction in other months. Demand in 2018 for fresh tomatoes was 2.5 million tonnes.[43]

CATFISH

In Nigeria, the fisheries sector plays significant roles in the economy and food diet, accounting for over 40% of domestic animal protein supply, with annual consumption reaching 14.2 kg per capita in 2015.[44,45] Native to regions across the country, and resistant to harsh environmental conditions, catfish is the major fish species cultured in Nigeria, accounting for roughly 64% of aquaculture fish production.[46,47] Estimates using this proportion put the production of catfish at 189,562 tonnes in 2017.[48] Artisanal fisheries contribute over 80% of the total fish production in the country, but the growth of the sector is threatened by post-harvest fish losses and high costs. For example, fish feed represents around 80% of inputs and is a major constraint responsible for high production costs.[49] Importantly, aquaculture has been identified as a potential alternative source of income for artisanal fisherman affected by conflict, as production at home can be safer than traveling to a body of water.[50]

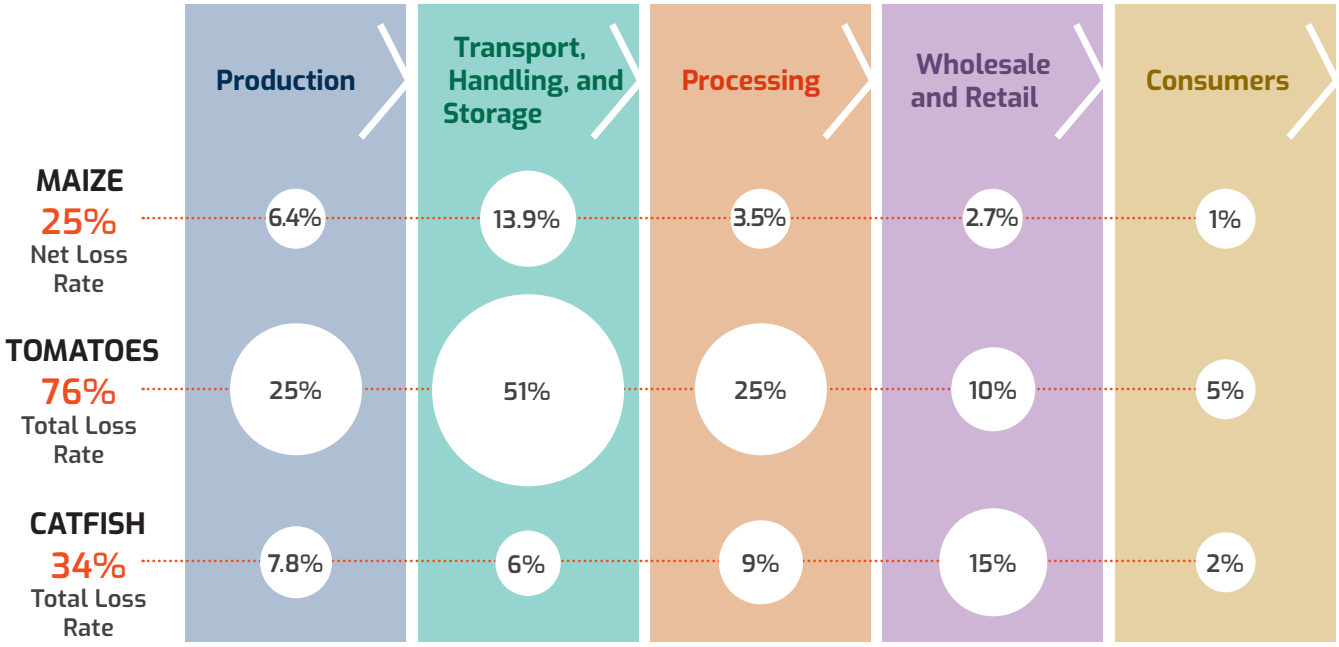
TOMATO PROCESSING

Tomato processing has been identified as a largely reliable method of reducing post-harvest losses.[51] In recent years Nigeria has seen significant growth in its tomato processing industry, triggered by national policy. Despite being an exporter of fresh tomatoes, Nigeria imports large quantities of tomato paste, which prompted the government to ban importation of tomato paste or concentrate put up for retail sale.[52] Tomato processing is growing, with expanding product range and increased acceptability in the local market. Companies are showing promising growth and increasing their processing capacity. One example is Tomato Jos, which opened a tomato processing plant in Northern Nigeria, aiming to produce 500 to 700 tonnes of product in 2020, expecting to triple the following year.[53] Another example is Patilad Wonders, which reached a tomato processing capacity of 1,361 tonnes per day in 2019.[54]

FOOD SAFETY HAZARDS OF SELECTED COMMODITIES

Aflatoxins have been observed along the maize value chain in Nigeria, including in farm storage, in containers used for transportation, and in processed maize products. For example, high levels of aflatoxin were detected in domestically processed maize products, including *ogi*, a widely used breakfast and weaning food.[55] For fresh produce, the key food safety concern is microbiological in nature and is likely a leading vector of foodborne illness implicating pathogens, such as *Salmonella, E. coli*, norovirus, and *Listeria monocytogenes*.[56] Produce can be contaminated at every stage of supply: during cultivation, at harvest, in washing, preparation, and processing, in transportation and distribution, and in food carts and kitchens. Little is known specifically about the food safety risk associated with Nigerian tomatoes, a product that is overwhelmingly destined for domestic consumption. However, fresh fruits and vegetables are thought to be a major source of foodborne pathogens in the Nigerian food supply, and tomatoes are heavily consumed within that category. Fish is a major and likely underestimated source of food safety risk in Nigeria, the predominant hazard being microbiological in nature, although chemical contamination is also a concern. Microbiological contamination is likely related to the use of untreated feces or unclean water in capture and aquaculture fisheries, coupled with unsafe handling and the lack of temperature along the supply chain. Other seafood safety risks stem from industrial water pollution and anti-spoilage agents, and in aquaculture specifically, the use of growth hormones, water additives, antimicrobials, and the use of aflatoxin-contaminated feed.

FIGURE 1. Food loss and waste hotspots along the value chain in Nigeria (loss percentages occur at each stage)*



Sources: APHLIS 2019; Gromko and Abdurasulova (2019); Adelaja, Kamaruddin, and Chiat (2018); and FAO (2011)[57]

Losses and waste occur at different locations along the value chain between maize, tomatoes, and catfish. Tomatoes have the largest total loss rate of 76%, with the greatest losses occurring during the first three stages of the value chain. Total catfish losses hover around 34%, while maize losses are the lowest at 25%. 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.

*The percentage of losses of tomato at the processing stage does not reflect the growth of the tomato processing industry. Numbers that account for processing are not yet available. However, we estimate that the percentage of losses would be lower than 25%.

Global Framework Highlights Impacts of Food Loss & Waste Interventions

Policymakers for Nigeria face competing policy goals. For example, the country may be interested in:

- Reducing food loss and waste;
- Improving farm welfare;
- Increasing food security;
- Reducing reliance on food imports;
- Reducing stress on natural resources and pollution through less farm production; and
- Decreasing greenhouse gas emissions.

Given Nigeria's burgeoning population growth and significant food insecurity, the country's driving policy priorities will likely be increasing food security, improving farmer incomes, and import substitution. To guide policy development, two types of analyses are necessary. First, what the potential of reductions in FLW is to contribute to the policy goals, and second, how alternative interventions compare in terms of their effectiveness and costs and benefits.

The Global and Conceptual Framework on Food Loss and Waste focuses on the first type of analysis – how a reduction in FLW contributes to policy goals.* The Global Framework is not a projection of how the food system will evolve with demographic and income shifts over time, but rather it provides a comparison between the current state of the food system with and without food loss and waste reduction. A detailed analysis of costs, benefits and effectiveness of alternative interventions would be the next step towards a FLW strategy. The Global Framework simulates the government's commitment of reducing food loss and waste by 50%. It then looks at where the reduction should happen to support Nigeria's key priorities of increasing farmer incomes and food security. The Framework allows for the estimation of how these reductions of losses at each stage of the food supply chain affect policy goals.**

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 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 Nigeria'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 and availability (as measured by net consumption prices), trade (exports), natural resource stress (as measured by farm production), GHG equivalent emissions, and total food waste. By jointly considering all stages of the supply 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 strategies.

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.

**Farmer welfare is defined as farmer net profitability, while food security is defined as household food availability.

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. For tomato, looking at production and consumption, Nigeria would be 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 in the south. However, considering current trade patterns–that is, large exports of raw tomatoes, imports of processed tomatoes, and the current growth of tomato processing industries–Nigeria is effectively a small open economy. For catfish, with a nascent industry and very small production globally with minimal trade, Nigeria is considered a closed economy. For staples, Nigeria is considered a small, open economy because staples tend to be transported better than perishables and Nigeria'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 MAIZE

The results highlight the potential for import substitution, as well as positive effects on farmer welfare and greenhouse gas emissions. As shown in Table 2, with reductions of losses and waste at any stage of the value chain, import substitution is possible, ranging from a reduction of imports by 5% at the lowest (consumer) stage up to 53% with a cut at the farm stage. With a 50% reduction of losses at the THS stage, where losses are the highest at 13.9%, Nigeria could switch from an importer of maize to an exporter.

For other objectives, including food security and farmer welfare, reductions of losses and waste provide negligible or positive impacts. Again, when implementing reductions of losses at the THS stage, where losses are the highest, as Nigeria flips to become an exporter, farmers see higher sales prices, prompting an increase in production and a subsequent

TABLE 2. 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	↑	↓	↓	↑	↓	↓
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

increase in farmer welfare. Effects are similar for interventions at the farm stage, albeit to a lesser degree. Except for interventions at the THS stage, changes in farm production is relatively neutral, with negligible increases, and therefore only marginal increases in natural resource stress. With primarily positive impacts on food security and moderately positive impacts on farmer welfare, this model demonstrates that Nigeria can use food loss and waste reduction policies to strongly support its priority of reducing reliance on maize imports, while also reducing its greenhouse gas emissions.

REDUCING LOSSES & WASTE OF TOMATOES

Results indicate that in an open economy scenario in Nigeria, there are minimal tradeoffs to weigh when addressing losses and waste of tomatoes, as nearly all objectives can be achieved. Nigeria is a small importer of tomatoes and consumption is dominated by domestic production. Less than 1% of total consumption is imported, but this is likely to amount to a larger share of consumption in urban areas and the south where the infrastructure can support some transportation of perishables. Nigeria 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 3 shows, when reductions in losses are made at any stage of the value chain, food security improves significantly, the greatest gains realized with interventions at the THS and processor stages, where losses are substantial.

Nigeria produces 4.1 million tonnes of tomatoes domestically, and imports only 709 tonnes, implying that even with losses of 76% of domestic production, Nigeria is essentially self-sufficient in terms of supplying its own domestic demand. This is evidenced by the important outcome that interventions to reduce losses and waste by 50% at any stage of the value chain provide massive import substitution potential – in fact, in all stages,

TABLE 3. 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	↑	↑	↓	↑	↓	↓
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

Nigeria becomes a net exporter of tomatoes. This effect is more dramatic in the case of tomatoes than in maize (above) because Nigeria imports very little volume of tomatoes, both absolutely, but also in relative terms compared to total consumption, in contrast to a heavier reliance on maize imports. Trade provides a buffer for farmers against potentially adverse indirect effects from price changes in response to reduction policies, and therefore production increases with reductions in losses at the farm and THS stages, corresponding to an increase in farmer welfare of 15% and 51%, respectively. Greenhouse gas emissions decline in every scenario, although most significantly with losses and waste reduced at the farm and THS levels.

For rural, marginalized, and conflict-affected areas of Nigeria in the north, 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, without the buffer of trade, cutting losses at the farm, THS, and processor levels, where losses are the highest, results in more tomatoes in the system, causing lower market prices, and hence lower production, which triggers a loss in producer welfare, as shown in Table 4. With these lower market prices and lower waste rates (and increase in available food), for interventions at every stage, food security improves quite significantly. 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.

REDUCING LOSSES & WASTE OF CATFISH

A nascent industry with limited production, all of which is destined for domestic consumption, farmed catfish in Nigeria is modeled under a closed economy scenario. The results demonstrate that there are virtually no negative tradeoffs when reducing losses and waste of catfish at any point in the value chain, as shown in Table 4. Importantly, food security is improved with interventions at any stage, with the highest increase when a reduction is made at the retail level, as the losses rate of 15% is the highest at that stage. With reductions at any stage, more catfish enter the value chain, and prices decrease slightly since production levels are already quite low and do not meet local demand. Therefore, with minimal negative pricing impacts with reduced waste, production levels correspondingly increase marginally, thereby increasing farmer welfare slightly as well. Similarly, the greatest food security benefit occurs when waste reductions are made at the retail level, with production increases (0.4%) and farmer welfare gains (1.25%) also being the greatest with a 50% cut of losses at this stage of the value chain. Correspondingly, the greatest reduction in food losses and waste along the entire value chain is achieved with interventions at the retail stage, achieving a 13% reduction in losses. Changes in greenhouse gas emisisons are nominal in all scenarios.

Table 5. Impact of reducing losses and waste of catfish at different points of the value chain (closed economy model)

CATFISH–CLOSED ECONOMY MODEL

	Farmer Welfare	Food Security	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 Maize, Tomato, and Catfish in Nigeria

The Global Framework suggests that interventions to reduce losses at all stages of the maize and tomato value chains, under an open economy scenario, provide significant opportunity for import substitution and, at times, the potential to grow exports. For both maize and tomato, in an open economy, there are limited, if any, negative tradeoffs when reducing losses and waste anywhere along the value chains. This is important to recognize, as not only can Nigeria use reductions in losses and waste to achieve a top priority of reducing dependence upon imports, but also in doing so, farmer welfare, food security, natural resource use, and greenhouse gas emissions will not be compromised. This demonstrates the multiple wins that addressing food loss and waste can provide for an open economy.

For rural, marginalized communities in Nigeria, especially those in the north disconnected from demand and affected by conflict, the effects and tradeoffs of losses and waste reductions of catfish in the closed economy are more pronounced. Interventions at any stage of the value chain lead to neutral, if not positive outcomes, for all policy priorities. Especially important, in rural regions where food insecurity and malnutrition are highest, is the small to significant rise in food security with a 50% reduction in losses and waste at any stage.

LOOKING FORWARD TO SOLUTIONS

The section below identifies some of the drivers of food loss and waste and associated policy interventions to reduce the inefficiency of Nigeria's value chain stemming from losses and waste. Early warning systems and access to real-time market information can help farmers make better planting and investment decisions, reducing risk mitigating actions that

lead to overplanting and losses. A focus on improved storage and harvesting techniques, in addition to increased private sector investments and improved road infrastructure, will be critical to reducing losses, especially in the remote regions of the north. Given the long distances that perishables need to travel from the north to reach the south, and the rising middle class that will demand more nutritious, perishable foods, Nigeria will also need to increase the capacity of its cold chain as its population doubles by 2050. The design of the cooling system needs a holistic plan, with thoughtful intervention around where investments should be made. To increase private sector participation, risk mitigation measures will need to be examined as well as improving the enabling environment. Finally, food waste already accounts for majority of landfill volume in Nigeria, releasing potent methane emissions; and by 2050, with around 70% of Nigerians set to live in urban areas, this issue will further stress land scarcity challenges, associated pollution, and rising costs for municipalities. Cities will need to invest in capacity, enforcement, and facilities to make more efficient use of food waste, for composting, waste-to-energy, or animal feed purposes, to ensure Nigeria can meet its Paris Climate Agreement commitment.

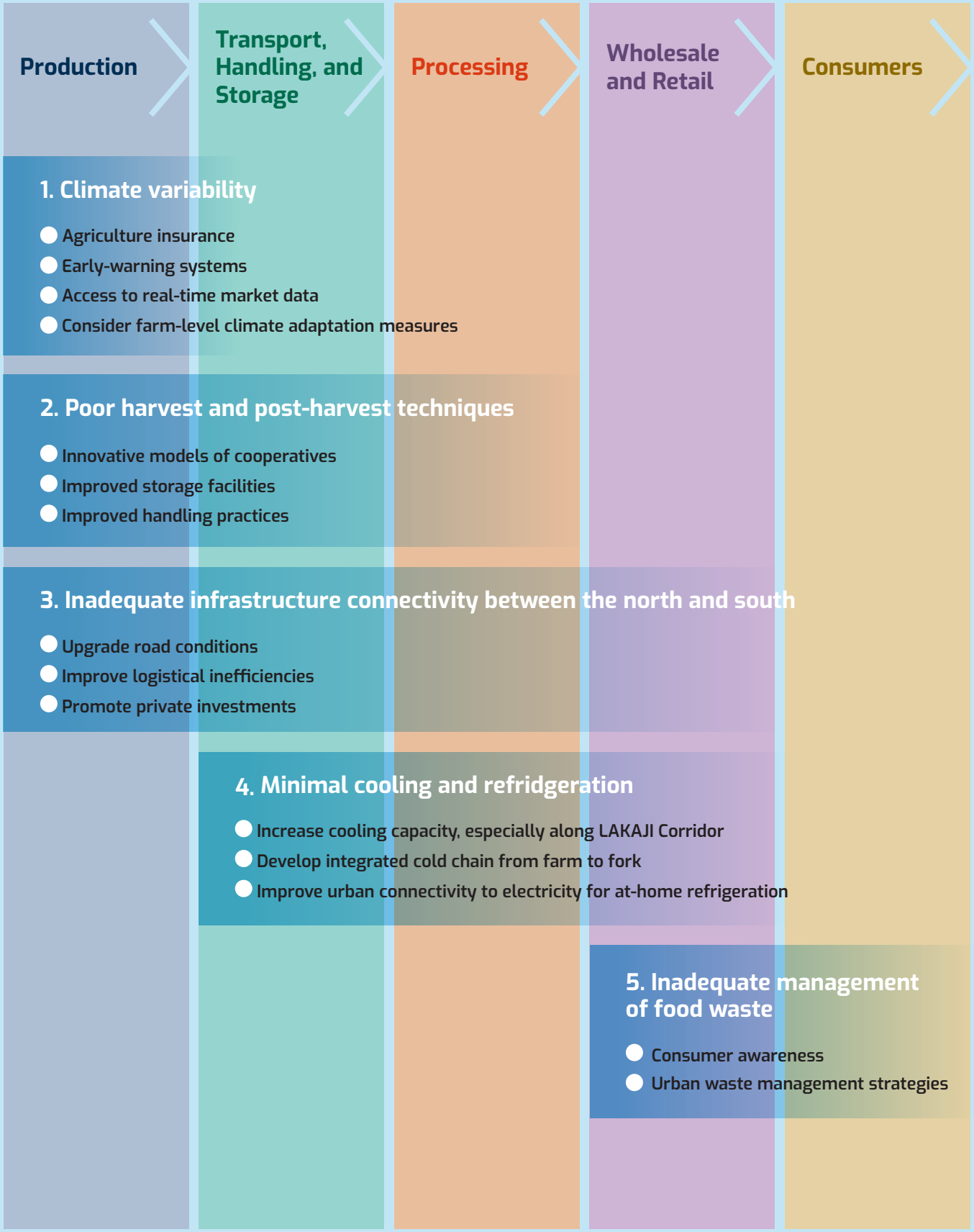
1. MARKET AND CLIMATE INFORMATION: DATA AND EARLY-WARNING SYSTEMS

Farmers in Nigeria are constantly facing the impacts of climate and market variability. Due to climate change, Nigeria's average temperature is rising and is expected to reach partial monthly mean temperatures of more than 30ºC for 2020-2039 under business as usual conditions.[58] As most of the population has no access to forecasting of erratic weather patterns, including floods and droughts, food loss and waste in Nigeria 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. Regional and seasonal differences of supply and demand also lead to losses in Nigeria. For example, the majority of tomato production occurs in northern Nigeria, while the largest demand is in southern Nigeria, over 1,200 km away. Perishables do not travel easily, especially without the aid of cooling, and it's been estimated that 41% off losses of tomatoes occurs during transportation. At the farm level, the seasonality of certain crops, especially perishables, leads farmers to leave a significant portion of crop in the field, when markets are saturated and prices are low.

Access to technology can play an important role in mitigating losses due to the lack of climate and market information. 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 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.

FIGURE 2. **Drivers of food loss and waste along the value chain in Nigeria for maize, tomatoes, and catfish**

● Policy Intervention Strategy



2. IMPROVED STORAGE AND HANDLING TECHNIQUES

Nigerian farmers face the hurdle of inadequate storage facilities and handling practices that affect the quality and safety of produce, all leading to increased losses. In metropolitan areas, modern silos and warehouses are used for storage, but the majority of farmers in rural areas only have access to traditional and improvised structures for storage, such as baskets, sacks, platforms, cribs, and sheds. Challenges associated with traditional storage methods include moisture penetration, rusting, molding, rodent infestation, roof leaks, and theft.[60] Poor handling practices crush tomatoes, expose maize to pests, reduce pre-frozen life of catfish, and increase the likelihood of foodborne illness implicating pathogens. A recent study found that switching the storage of tomatoes during transportation from traditional baskets to plastic crates reduced losses from around 41% to as low as 5%.[61] Inadequate storage and handling effects are exacerbated by Nigeria's unreliable power supply in rural regions,[62] where it is estimated that around 50 million Nigerians lack electricity and basic refrigeration.[63]

Small-holder farmers can reduce losses by gaining access to improved storage and handling techniques through farmer cooperatives. Additional benefits of joining cooperatives, especially in remote areas, include a reduction in sales below market prices,[64] better access to loans and finance, and centralized investment for infrastructure and inputs. Importantly, farm cooperatives can centralize access to market and climate data and can guarantee the sale of their produce at a fair price.[65] A farmer sample study in Nigeria showed that 74.5% of farmers that are part of some type of cooperative are non-poor, compared to 59% of farmers that are not part of a group.[66]

However, innovative and effective models of organizing farmers are much needed. Existing traditional models of cooperatives have not generated the desired impact. For example, cooperatives in Ebony State have contributed to agricultural development but there are several problems that have hindered growth: organizational issues about their expected roles, low incomes and poor government interventions.[67] Generally, cooperatives in Nigeria suffer from poor management, lack of cooperation and lack of commitment.[68]

3. IMPROVED CONNECTIVITY: TRANSPORT & ROADS

Two overarching issues related to poor connectivity are fragmentation of value chains and weak private sector investments. Prevalence of smallholder farmers generated fragmented land holding with low access to credit.[69] Production fragmentation slows down growth in the value chain, especially in countries with little to no private sector investment.[70] In that context, Nigerian value chains have been plagued by poor infrastructure, low investments, and unfavorable government policies, which leads to a poor enabling environment for private investments.[71] Despite recent policy reforms within the government, the agriculture sector still requires large investments that need to be scaled up by encouraging private participation.[72] Private sector involvement (from large companies to small-scale famers and their organizations) is critical if agriculture is to contribute effectively to food and nutrition security[73] and to improve infrastructure.

Although tomato production can be found around the country, many of Nigeria's agricultural production zones are located in the north, yet wholesale and consumer markets are primarily located in the south. This created the need for long-distance transportation routes, the most commonly used known as the LAKAJI (Lagos-Kano-Jibiya) Corridor: Nigeria's largest

agricultural trade corridor, as shown in Figure 3. The LAKAJI Corridor is 1,225 kilometers long and runs along eight major states, where almost 30% of Nigeria's population is located. Therefore, besides being a critical transportation route for agricultural products, it also connects the interior of the country with international markets and is a major conduit for food supply from the north to the south.[74]

Despite recent infrastructure projects that have significantly improved the conditions of the LAKAJI Corridor,[75] some sections are still characterized by poor road conditions, severe congestion due to traffic accidents or disabled trucks, security checkpoints, and flooding from heavy rain, which can stall cargo for extended periods of time, mainly in the northern areas.[76] For example, passing Kano and going towards the Nigerien border at Jibiya, there can be as many as one security roadblock every two kilometers.[77] All of these inefficiencies leave crops and produce in the transportation stage for much longer than ideal and without cooling, leading to increased losses. Figure 4 demonstrates the poor logistical and efficiency performance of the LAKAJI Corridor compared to peers, showing the time and monetary costs of transporting goods along the Corridor compared to comparable routes in other countries. Improvements to this transportation corridor are also a critical enabler to drive continued private sector investment in Nigeria's agricultural sector.[78]

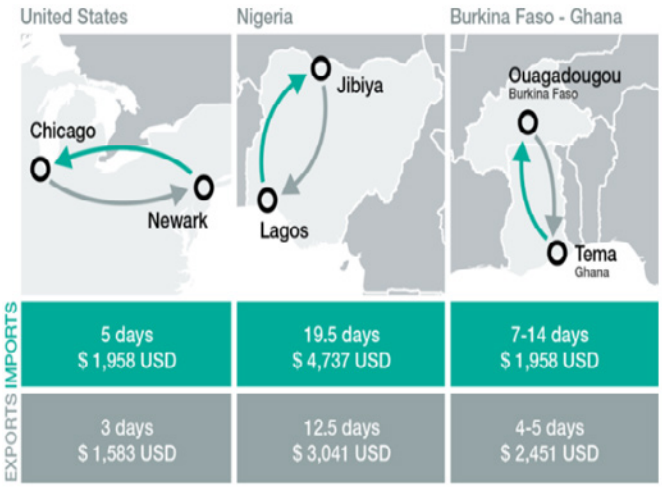
4. REFRIGERATION ALONG THE VALUE CHAIN

Nigeria faces significant risks due to a lack of access to cooling fans, refrigeration and other forms of cooling that can protect food, among other benefits.[79] A reliable and efficient cold chain system will not only help to significantly reduce the losses in quality and quantity of fresh fruits, vegetables, and proteins, but it will also improve the efficiency of supply chains and help to deliver safer and more nutritious foods to consumers.[80] It is estimated that 37% of Nigerian agricultural production requiring refrigeration is lost due to inefficient or non-existent cold chains.[81] Food spoiled from lack of cold storage causes 93 million small farmers in Nigeria to lose 25% of their annual income.[82] Climate variability, overproduction, seasonal variation of supply and demand, and long transportation routes increase the urgency to implement cooling and refrigeration systems throughout the value chain.

FIGURE 3. The LAKAJI Corridor

Source: Gromko and Abdurasulova (2019)

FIGURE 4. Time and Cost Benchmarking Exercise Along the LAKAJI Corridor



Source: World Economic Forum (2014)

Since tomato and catfish are highly perishable commodities, an appropriate cold chain at each step of the food supply chain is key to preserving food quality and preventing losses. With a consumer preference for fresh and live catfish, coupled with a lack of cold storage facilities outside of Lagos State, wholesalers and retailers in the north must handle fresh fish for a very short amount of time before selling to consumers – usually within 12 hours, increasing the risk of losses.[83] In addition, lack of appropriate cooling at home generates consumer food waste as well. Over 40 million urban dwelling Nigerians have little or no access to electricity to refrigerate food or to run cooling devices when urban temperatures soar.[84] Nigeria's cold chain capacity is on the rise, however, increasing from 10,000 cubic meters in 2014 to 200,000 cubic meters in 2018, an increase of 20 times. Yet all of this development has occurred in the south in Lagos State, primarily for storing frozen foods such as chicken, turkey, and fish.[85] With a focus on increasing isolated cold storage capacity in the south, rather than development of the entire cold chain through the LAKAJI Corridor, cooling connectivity issues faced in Nigeria remain significant and will continue to contribute to losses.

5. URBAN WASTE MANAGEMENT

Poor solid waste management has caused some Nigerian cities to be ranked as the most polluted and least livable cities in the world.[86] The country's population growth has not been matched by adequate funding and infrastructural facilities to sustainably manage the ever-growing volume of waste, currently totaling around 42 million tonnes annually, 52% of which is food waste. Waste collection is done mostly by state governments in partnership with private companies, but only around 50% of waste generated is disposed through official waste containers, while the rest is disposed by open dumping.[87] The generation of potent methane emissions from food waste represents a significant threat to Nigeria meeting its climate commitments. With an estimated 70% of Nigerians, or 280 million people, living in urban areas by 2050, as incomes rise and diets shift to include a greater proportion of perishables and proteins, Nigeria's landfills will be increasingly stressed, and harmful emissions will rise if a holistic solid waste strategy is not implemented. Beyond infrastructure and planning, Nigeria's local governments face challenges related to capacity, enforcement and consumer awareness.[88] Raising consumer awareness of food waste, increasing access to at-home refrigeration, and better packaging, labeling and standards will all help to reduce the amount of food waste reaching landfills in Nigeria. With experience in waste-to-energy production, Nigeria has the opportunity to convert collected urban food waste into biogas and reduce associated harmful environmental impacts, but this will require a coordinated effort by municipalities, consumers, and the private sector.

Key Conclusions & Next Steps

CONCLUSIONS

- Nigeria's future food system will be driven by a booming population, growth in urban centers, severe climate change impacts, and the need to feed its people a nutritious, safe diet. Rural demand for food is expected to decline, as 70% of Nigerians are expected to live in cities by 2050, although food insecurity will more acutely affect the remaining rural population. With a heavy reliance upon primary food imports, the country will likely seek to reduce food imports and increase self-sufficiency through its own domestic production.
- As shown by the Global Framework, for all open economy scenarios, Nigeria will not face a negative tradeoff between reducing losses and waste of either maize or tomatoes 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 significant 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 Nigeria 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 Nigeria.
- The open economy results also demonstrate a high potential for import substitution for both maize and tomatoes, a key policy priority for the government. When a 50% reduction in losses is achieved at the THS stage for maize, Nigeria could become an exporter of this commodity. For tomatoes, a 50% reduction in losses and waste at *any* stage of the value chain could result in Nigeria switching from a net importer to a net exporter. An important caveat to note, however, is that Nigeria does not yet have the necessary infrastructure to support the export of perishables. However, this analysis does not reflect the growing tomato processing industry, which may lower losses numbers at the processing stage of the value chain. As discussed above in the Key Loss Drivers section, Nigeria's transportation routes, logistics, and cold chain infrastructure are all insufficient to efficiently bring high quality perishables from the north to the south for export. This case reveals the imperative to promote private sector investment and expand the sector's approach from an intense focus on productivity to also include Nigeria's broader food system and its many interconnected components that require holistic strategy, a safe enabling environment for the private sector, and planning to achieve desired goals.
- The Global Framework highlights important policy tradeoffs that the government will face when reducing losses and waste in rural, disconnected regions of Nigeria where food insecurity and malnutrition are highest. For catfish in a closed economy scenario, with reductions of losses at any stage of the value chain, at-home consumption prices decrease, significantly improving food security. At the same time, with excess supply in the market, prices fall, and farmer welfare decreases. For these poor and conflict-affected regions in the north, food security is a top priority, and it is clear that

reductions in losses and waste will provide an immediate and significant boost to food availability and affordability. However, the government will need to explore social safety net options to ensure that farmers are not adversely impacted by this approach.

- To implement this strategy, policymakers should focus on reducing losses closer to the farm in rural regions where the impacts on food security and undernourishment will be significant, as well as reducing losses in the middle of the value chains so that production in the north can more efficiently meet the demand of consumers and (eventually) exports in the south. The supply chain is currently not up to the task of delivering the high quality and quantity needed by urban centers and markets in the south, and the policy recommendations focus on improving its capacity and efficiency. Promising areas of intervention include (i) early warning systems for farmers to reduce climate variability risks as well as access to real-time market information and prices to make more informed planting and investment decisions; (ii) improving storage facilities and handling practices, potentially reshaping current models of cooperatives; (iii) investing in public infrastructure with participation of the private sector to upgrade critical road infrastructure, address fragmentation of value chains for logistics performance, and reduce the amount of time that perishables are sitting on trucks in unfavorable conditions; (iv) increasing the cold chain capacity along the entire value chain for perishables and proteins, to ensure a longer shelf life and lower the likelihood of foodborne illness pathogens; and (v) for urban areas, establishing solid waste (and food waste) strategies, formalizing food waste collection and processing, and increasing consumer awareness of the issue to begin to manage its massive food waste challenge, reduce methane emissions, and find productive reuses, such as for waste-to-energy or animal feed purposes.

NEXT STEPS

Reducing food loss and waste is a promising strategy that can contribute to key policy goals of Nigeria, including reducing its reliance on food imports and increasing food security where it is most needed.

These results indicate that reducing food loss and waste bears potential benefits for Nigeria 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 Nigeria's food loss and waste strategy should be based on a careful analysis of alternative interventions, their associated costs, benefits, feasibility of implementation, and effectiveness in reducing losses and waste, 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 Nigeria's interest.

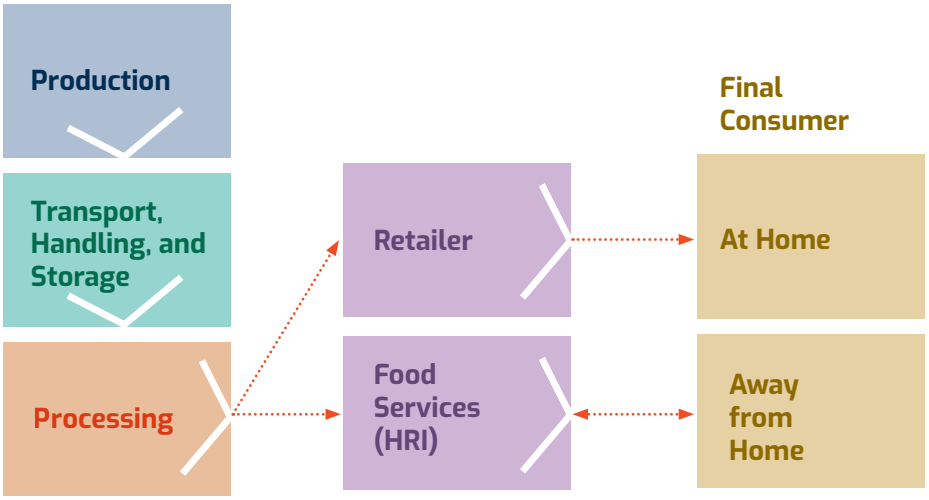
Technical Annex: Global Framework

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.[89] 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



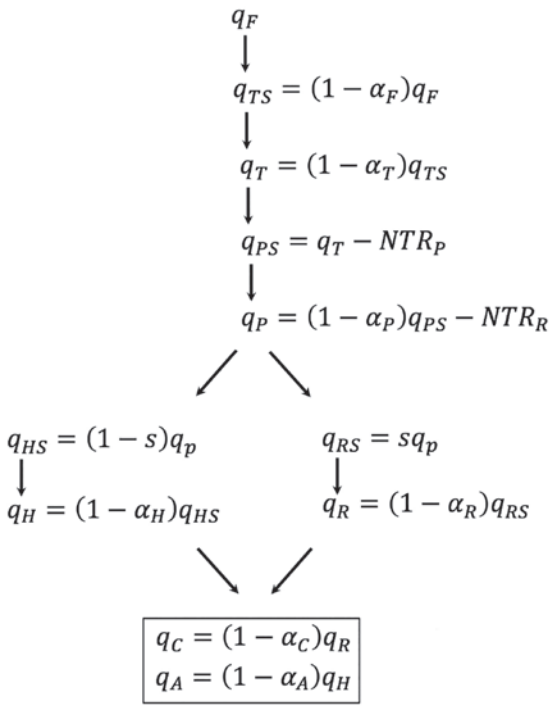
The model shows that the direction and magnitude of the indirect effects depends on the interaction of supply and demand elasticities at each level of the chain. The price elasticity of consumer demand in particular plays a key role in determining the effects of policy interventions at different stages 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[90] versus the elasticity of import demand (export supply) of the country[91] 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



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 Nigeria'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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90 The country's share of the world market is a major factor determining the size of the trade elasticity facing a country.

91 The ratio of domestic production (consumption) to imports (exports) is a major factor determining the size of the trade elasticity of a country.