REDUCING POSTHARVEST LOSS IN LIBERIA: TOWARD A FRAMEWORK FOR REDUCING FOOD LOSS IN LIBERIA

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by

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ABSTRACT

This paper presents a framework for tackling postharvest loss in Liberia. It is informed by evaluating efforts to address this issue using case studies. Drawing on the food loss literature, the assessment focuses on four projects: i) The lost food project, ii) WFP postharvest loss venture, iii) Postharvest management in Sub-Saharan Africa, and iV) Fenik cool box. The resulting framework adopts a circular economy approach to tackling conventional practices and seeks to close loops in the food system. Most importantly, it promotes sustainable and resource-efficient policies and actions for long-term socioeconomic and ecological benefits. Liberia has struggled with food insecurity for many years, and research has shown that postharvest loss is one of the factors contributing to food insecurity. Additionally, postharvest loss negatively affects the environment and public health in the country, thus negatively affecting the livelihood and well-being of its people. A robust intervention to address postharvest loss incorporates local dynamics and is best addressed through partnerships, using a system thinking approach involving multiple stakeholders at various levels.

BIOGRAPHICAL SKETCH

Jarsm Famatta Russell was born in Monrovia, Liberia, on January 24, 1994, into a loving family. She was introduced to Agriculture by her mother at an early age and grew up caring for nature and gardening. As time went by, a hobby turned into a passion that inspired Jarsm to pursue a degree in Agriculture. She has a Bachelor of Science degree in Crop Science (Horticulture pathway), having graduated in 2017 from the University of Botswana in Gaborone. Before starting the MPS program at Cornell, Jarsm worked in Liberia for Fauna & Flora International (FFI), a UK-based biodiversity conservation NGO, as Governance and Livelihood Assistant for the Southeast Landscape. She joined FFI in August 2018 as a Research Assistant through a paid internship and was based at the Sapo Conservation Centre in Sapo National Park. The Park, Liberia's largest and oldest protected area, is a biodiversity hotspot that houses many rare and endemic species. Over the three years she worked with FFI, she supported community engagement activities, focusing on awareness-raising, governance, livelihood, and capacity building. Through extensive interaction with members of the communities and becoming friends with many of the local women with whom she worked, she developed an interest in understanding ways to improve the livelihood of farmers in rural communities. The main livelihood activity for members of these communities is subsistence farming through shifting cultivation using the traditional slash and burn systems. With limited livelihood options and opportunities, those living close to protected areas and other places of high conservation value face additional challenges with restrictions on access and use of resources. Local farmers face food spoilage and waste due to a lack of appropriate storage and limited access to markets to trade their produce. Jarsm believes that at the end of her program at Cornell, she can gain insight into the food system to explore innovative ways to maximize the value of potential food waste into products that can bring additional earnings to rural farmers, primarily women. She is passionate about working with local communities, especially women, to design practical solutions supporting sustainable livelihood and reducing poverty.

This work is dedicated to my parents.

ACKNOWLEDGMENTS

I have always been fascinated by agriculture, and participating in this program has only increased my interest in understanding how to improve agriculture practice as a fundamental aspect of development. Through the capstone project, my assumptions have been challenged and confirmed, and I have had to look critically at issues I took for granted. I have concluded that achieving sustainable agricultural production is complex and interwoven with a lot of problems requiring the involvement of multiple actors from the government, non-governmental, private sectors, and communities. This has been a rewarding exercise, and I am confident that maybe I now know just a little more about how to address issues around food loss, which will be helpful to me in my practice as a development practitioner.

Participating in this program has been a life-changing experience, and I am grateful to many persons who have helped me along this journey. To Professor Terry Tucker and Maricelis Acevedo, I say a big thank you for the leadership you have shown in guiding me throughout the year; your actions epitomize leadership in practice, and it was a privilege to study under your tutelage. Many thanks to all those who lectured during the two semesters; you did a great job bringing clarity to many complex issues. Thanks to the Department of Global Development and the Institute for African Development for providing me with the scholarship that enabled me to honor my admission to the course. I am humbled and grateful for the trust shown in my ability. I am fortunate to have been a part of a fantastic group of students this year, making the program exciting and fun. Your passion, genuine concern for issues, and willingness to share your experience enriched my learning.

A special thank you to Professor Maricelis Acevedo and Dr. Theresa Pendergrast for being my academic advisors and helping me navigate the completion of the capstone project. I have learned a lot over the last

eleven months and appreciate the time and effort you have invested in this. Special thanks to my mentor and former supervisor at Fauna & Flora, Mr. Shadrach Kerwillain, for motivating me during difficult periods and providing guidance that has enlightened me. Your encouragement and advice are highly appreciated and cherished. I am grateful for all that you have done for me in helping me reach my goals and dream big. Special thanks to my host in Ithaca, Ms. Jackie Sayegh, who made my stay a pleasant affair. You went above and beyond for me, and your kindness humbled me.

Thanks to my family and friends for all the support you have provided me over the years. You have all contributed in one way or another to molding me, and for that, I am grateful. I reserve special thanks to my parents, Mr. James Nathanial Russell and Mrs. Margaret Russell, for making this project possible by teaching me the value of education. This would not have been possible without your nurturing, love, and admonishment. I will continue to do my best to make you proud.

Contents

ABSTRACT ..... **II**

BIOGRAPHICAL SKETCH ..... **III**

ACKNOWLEDGMENTS ..... **V**

LIST OF FIGURES **1**

LIST OF ABBREVIATIONS **2**

CHAPTER 1: INTRODUCTION **3**

BACKGROUND 3
AIMS AND OBJECTIVES OF THE STUDY 5
THEORETICAL APPROACH 5
THE SCALE OF THE PROBLEM 6
COUNTRY PROFILE: CURRENT POSTHARVEST FOOD LOSS SITUATION IN LIBERIA 9

CHAPTER 2: LITERATURE REVIEW **11**

SCOPE OF POSTHARVEST FOOD LOSSES OF FRESH FRUITS AND VEGETABLES 11
CAUSES OF POSTHARVEST LOSSES OF FRUITS AND VEGETABLE 12

CHAPTER 3: CASE STUDY EVALUATION **15**

I: THE LOST FOOD PROJECT 15
II. WFP POST HARVEST LOSS VENTURE 20
III. POSTHARVEST MANAGEMENT IN SUB-SAHARAN AFRICA 23
IV: FENIK COOL BOX 25

CHAPTER 4: CONCEPTUAL FRAMEWORK TO REDUCE POSTHARVEST LOSS IN LIBERIA **27**

CHAPTER 5: CONCLUSION **32**

REFERENCES **34**

LIST OF FIGURES

Figure One: Project Design for The Food Loss Project'

Figure Two: Strategies, tools, and Outcomes for The Food Loss Project

Figure Three: Business Model for Hermetic Storage in Mozambique

Figure Four: Conceptual Model for a PHL Mitigation Framework for Liberia

LIST OF ABBREVIATIONS

FLW	Food Loss and Waste
PHL	Postharvest loss
PHFL	Postharvest food loss
FAO	Food and Agriculture Organization
WFP	World Food Program
GDP	Gross Domestic Product
GHI	Global Hunger Index
SSA	Sub-Saharan Africa
LISGIS	Liberia Institute of Statistics and Geo-Information Service
MoA	Ministry of Agriculture
USAID	United States Agency for International Development
EPA	Environmental Protection Agency

CHAPTER 1: INTRODUCTION

Background

Postharvest food loss and waste can be defined as the decrease in the quantity or quality of the edible part of the food produced for human consumption at any point along the food supply chain or postharvest system (Parfitt et al. 2010, Spurgeon 1976). Malfunction of the food production and supply system or its institutional and policy framework is the primary cause of food loss (Voza, 2020). This could be due to managerial and technical limitations, such as a lack of proper storage facilities, cold chains, proper food handling practices, infrastructure, packaging, or efficient marketing systems (Rezaei et al., 2017). On the other hand, food waste is the removal of food from the supply chain that is still fit for human consumption (FAO 2013). This removal is done by choice or after the food is spoiled or expired (Rezaei & Liu, 2017).

Food waste typically but not exclusively happens at the retail and consumer levels (Rezaei et al., 2017). In contrast, food loss occurs at the earlier stages of the food supply chain – during production, postharvest, and processing. Therefore, it is essential to distinguish between food loss and food waste as the solution to address these problems must be grounded in a holistic understanding of their causes. Food loss and waste (FLW) represents the wastage of resources, including the land, water, and energy used to produce food, leading to diminished natural ecosystems and services (Lipinski et al., 2013). Furthermore, it strongly contributes to climate change because greenhouse gases are emitted during food production and distribution activities, and methane is released during the decay of wasted food (Kaza et al., 2018). Additionally, this inefficiency in the food systems leads to economic loss for farmers and sellers and high prices for consumers. Finally, it affects the food supply chains by lowering income for food producers and reducing access to food.

What is particularly upsetting about the loss and waste of food is that millions of people are hungry worldwide. Thus, improving food systems to reduce food losses and waste can directly reduce food insecurity and help mitigate climate change, both of which are global socio-ecological priorities. Toward this goal, Target 12.3 of the Sustainable Development Goals calls for halving per capita global food waste at both consumer and retail levels by 2030 and reducing food losses along the production and supply chains, including postharvest losses (Abualtaher, 2020). However, with nine years left to reach its targets, there is an urgent need to accelerate action to reduce food loss and waste if this is to be successful.

Food loss and waste contribute to societal problems as the land, water, energy, and other natural resources utilized to grow, harvest, transport, and package food are underutilized, negatively impacting food security and environmental sustainability. Despite significant improvement in our ability to grow more food, more than 800 million persons will suffer from hunger worldwide in 2020 (Kiliç, 2022). Furthermore, as a sector, FLW is the third-largest contributor to global GHG emissions (Scialabba, 2015). Investing in systems and technologies to help tackle food loss and waste will benefit society, with a positive socio-ecological impact benefiting people, biodiversity, and the environment. This can be seen as a win-win-win, with farmers enjoying an increase in profit, consumers being able to purchase food at more affordable prices, and reduced negative impact on the environment, including GHG emissions. Exploring how the agricultural, social, ecological, and economic components of FLW are interconnected and influence one another is an essential first step toward addressing the problem. However, workable solutions to address FLW must be informed by local circumstances that promote a holistic approach and consider the entire system's ensemble of processes and feedback.

Aims and Objectives of the Study

This paper aims to evaluate the effect of postharvest loss on food insecurity and how Liberia can learn from other countries that faced a similar problem and find a context-based solution. The paper also aims to research what others are doing to implement postharvest food losses in markets to recommend solutions that would be beneficial in reducing the number of wasted fruits and vegetables or going to landfills daily. Finally, this paper's objective is to become a framework for the government or people looking to invest in postharvest handling to guide them and give them the necessary tools to help reduce postharvest losses.

Theoretical Approach

In the absence of primary research, a literature review is an excellent way of synthesizing existing research findings to find connections and show evidence on a meta-level, as well as a way of gaining insight into problems that can be contextualized. Hence, a literature review can be seen as a critical component of creating theoretical frameworks and building conceptual models that can be made more targeted through research. A properly structured, thorough, and well-conducted review creates a firm foundation for advancing knowledge and facilitating theory development (Webster & Watson, 2002). Importantly, by integrating findings and perspectives from many empirical findings, a literature review can clarify the current state of a topic by showing what has been tried, albeit under conditions that might be different from what the researcher seeks to elucidate.

One often-overlooked advantage of a literature review is that as the various studies were often conducted using different multiple disciplinary lenses, one can draw conclusions across disciplines, improving the explanatory and predictive potential of the framework developed through the review. However, complementing a literature review with another strategy can make

the insight gained more robust and applicable. Toward this goal of improving the research finding, a literature review can be complemented by a program evaluation to judge the worth or utility of a program (or alternative programs) in improving some specified aspect of a system, vis-a-vis what it set out to do.

Specifically, I want to complement my literature review with the use of a theory of change evaluation to understand what worked well or did not and why. In addition to the assessment of existing literature, I will adopt a case study approach to take a closer look at selected project interventions to address postharvest loss. Combining the findings from these two methods will then inform a framework and outline research gaps in addressing postharvest food loss in Liberia.

The Scale of the Problem

The current global food system is inefficient and unsustainable beyond debate, which has led to the FLW crisis across the global food system. The situation's urgency is demonstrated by the fact that an estimated 30% of the food produced for human consumption is lost or wasted along the food supply chain (FSC) (FAO, 2015). This amounts to 1.3 billion tons of food per year. The FAO (2015) estimates that the value of annual FLW at the global level is approximately US$ 1 trillion, and the United Nations stated that 14 percent of global food produced is lost between harvest and retail.

In comparison, an estimated 17 percent of total global food production is wasted (11 percent in households, 5 percent in the food service, and 2 percent in retail) United Nations (2021). Loss and waste can be seen in every stage of the food system, from production (especially in low- and middle-income countries) to consumption (mainly in high-income countries). Furthermore, when one considers projections that the global population will increase by three billion over the next 30

years, requiring a 70% increase in food availability, the enormity of the scale to feed the world sustainably becomes clearer. FLW is an issue with far-reaching negative implications, posing a challenge to food security, food safety, the economy, and environmental sustainability.

The United Nations Environment Programme's 2021 Food Waste Index has found that an estimated 931 million tonnes of food end up in the trash every year. Of this amount, China and India, the world's two most populous nations, placed first and second, respectively, with an estimated 91.6 and 68.8 million tonnes of food discarded annually. In the U.S., an estimated 19.4 million tonnes of food was dumped in 2021. At 53%, cereals comprise the largest share of global food loss and waste by caloric content (53%), while meats are a relatively small share at 7% (Vilariño et al., 2017). However, the amount of FLW varies between countries and is influenced by the level of income, urbanization, and economic growth. The United Nations Environment Programme's 2021 Food Waste Index has found that an estimated 931 million tonnes of food are wasted in the trash yearly. Most of that figure, 569 million tonnes, falls under household waste, while the food service and retail sectors account for 244 and 118 million tonnes. To put this into further perspective, according to Gustavsson et al. (2011), the amount of food waste in industrialized countries at the time (including China and the United States) was approximately 222 million tons, which was nearly equal to the total net food production in Sub-Saharan African countries at 230 million tons.

The latest statistics recorded by UNEP show that the scale of the problem has been dramatically underestimated, with the global waste at the consumer level more than twice as high as a previous FAO estimate. With growing attention to FLW since 2008, numerous technological and

institutional strategies have been proposed to reduce FLW at local, regional, and global levels (see Wang et al., 2021; Vilariño et al., 2017 for comprehensive lists). However, it is critical to understand that effective FLW reduction strategies are region or country-specific; they are adapted to local situations (e.g., energy limitation, infrastructure limitation). Both food loss (mainly in developing countries) and food waste (mainly in developed countries) are targeted differently to address the factors driving FLW adequately. Furthermore, barriers vary by region, FCS stage, and supply chain actors, including institutional regulations, limited financial sources, constraining resources (e.g., energy), and information gaps (e.g., retailers). In addition, consumers' behaviors are associated with the underlying causes of FLW discussed in the previous section.

One of the most potent ways to address FLW in developing countries relates to developing infrastructure along the whole food supply chain. This includes handling, processing, transport, cold storage chain, and market facilities. However, the significant barrier to implementing this solution is energy availability and the high cost for stakeholders, including farmers, government, and market women vendors. In addition, capacity development, including aiding farmers to source funding, but unavailability of bank loans to local farmers means they cannot get the training they need and access to farm inputs.

According to (Aschemann-Witzel, 2015), better retail management and targeting consumers' behavior in developed countries seem to offer the best entry point. But policies need to be enacted to incentivize all actors along the FSC to reduce waste. Unfortunately, behavior change is seemingly the most difficult at the household level since there is usually no punishment for consumers.

Country Profile: Current postharvest food loss situation in Liberia

According to the WFP (2022), Liberia is one of the least developed, low-income, food-deficit countries. The Emergency Food Security Assessment in 2015 found that food insecurity affects 16 percent of households, including two percent severely food insecure. This means that poverty and food insecurity are high across the country, particularly in rural Liberia, which is home to 51% of the population. Approximately 83.3 % of the population lives on less than $1.25 daily. In the 2019 Human Development Index, Liberia ranked 176 out of 189 countries and 112th out of 117. The GHI ranges from 0.0 to 50.0, and Liberia's score was 34.9, indicating the country's hunger levels are 'serious' and on the brink of becoming 'alarming' (Global Hunger Index, 2019).

Over the years, agriculture has proven to be one of the major backbones in the country's effort to reduce poverty and food insecurity. It relies heavily on small-scale subsistence farming for its income, nutrition, food, and survival. Agriculture, including forestry, accounts for 31% of Liberia's 2020 GDP and is also the main livelihood for more than 60% of the country's population (International Trade Administration, 2021). Agriculture in Liberia is focused mainly on cultivating food crops such as rice, cassava, plantain, etc., and exporting commodities such as rubber, oil palm, cocoa, and timber to feed its population.

It is surprising to note that though agriculture is the primary livelihood for over 60% of the population, the country still cannot feed itself and has a significant amount of food insecurity and poverty. Postharvest food loss is among the major underlying causes of poverty and food insecurity, with several challenges that have prevented sustainable agriculture in Liberia. Challenges such as poor road connectivity, lack of infrastructure, storage facilities, high transportation, and low electricity access are high on the list (Aworh, 2021).

Furthermore, due to poor pest management and lack of technology, the limited use of fertilizer, and modern-day cultivation methods, Liberia lacks good quality farm inputs, which shows that there is little incentive to produce food beyond subsistence levels (International Trade Administration 2021). Because of the country's poor economic condition, many farmers cannot manage large acres of land as most of the farming is done manually. This has led to a lack of motivation from farmers to produce on a large scale and has resulted in growing only for household consumption. About 80% of the food sold on the Liberian market is imported from neighboring countries like Guinea and Ivory Coast and some countries in Europe, the Americas, and Asia (International Trade Administration 2021). When thinking about the problem of food insecurity in Liberia and the number of farmers and market women, the first questions that come to mind is; how can farmers and market women properly manage what is locally grown to zero out postharvest food loss waste? What assistance is required to reduce poverty and food insecurity? How can we motivate farmers and market women to grow and purchase locally? What can we do to reduce the amount of food that goes to waste from farm to market? What can we learn from other countries with similar problems?

Moreover, food loss and waste contribute significantly to pollution around open markets within the country. Organic waste (fruits, vegetables, food scraps, paper, cardboard, wood) is one of Liberia's highest components of municipal solid waste in marketplaces. Value addition, preservation, and storage are essential to reduce pollution in open marketplaces. What interventions can Liberia use to manage its food waste system and utilize these resources?

CHAPTER 2: LITERATURE REVIEW

There is limited academic research in the existing literature on postharvest food loss of fruits and vegetables, its impact, and prevention strategies in Liberia. Due to my inability to travel to Liberia to conduct primary research, I have reviewed the academic literature on studies from other countries that have faced similar challenges and have a context similar to Liberia. Besides academic journals, this paper also examines project interventions and government policies (including existing systems and processes) to identify the gaps and challenges associated with postharvest loss.

Scope of Postharvest Food Losses of Fresh Fruits and Vegetables

According to Owusu – Sekyere (2011), the continent of Africa still has an incredible amount of arable land to produce food to feed its growing population. Yet, the continent continues to suffer from acute food insecurity. Food that is planted for consumption (e.g., cereals, fruits, vegetables, tubers, legumes) and dairy products together account for 92% of total food losses in developing countries, with the remaining 8% being meat (4%) and fish (4%) (Kader et al. 2012). These losses usually occur mainly between the production and retail stages of the supply chain. Within the plant food component, fruits and vegetables account for the most losses, estimated to be 50% or more (Ambuko, n.d.).

The annual net food production in Sub-Saharan Africa (SSA) is 230 million tons (Gustavsson et al., 2011). However, more significant portions of this amount are lost due to various factors ranging from poor infrastructure, unstable electricity, low levels of technology and low investment in the food production systems, pests, inadequate policies, storage, climate, and other factors (Andah, 2000; Gustavsson et al., 2011).

All these show the urgency and importance of preventing or minimizing fresh fruits and vegetable losses. Therefore, to cope with food insecurity while reducing food loss, it is vital to improve postharvest technologies, for example, good harvesting practices and packaging systems, to minimize postharvest losses and improve fresh produce's quality and availability.

Importantly, with the increased stress on agriculture linked to climate change, the need for a more efficient and resilient food system is increasingly being discussed (Bechoff et al., 2022). PHL increases with temperature, with fruits and vegetables especially vulnerable (Cruzi et al., 2022). This means that the projected rise in global temperature will increase vulnerability to PHL, with negative implications for efforts to address food insecurity and fight poverty, including meeting the targets of Goal 2 of the Sustainable Development Goals - End hunger, achieve food security and improved nutrition, and promote sustainable agriculture. This is ironic, considering agriculture's role in climate change and global biodiversity loss, indicating that PHL can be regarded as part of the vicious cycle of poverty. Therefore, addressing PHL can be seen as vital in making agricultural systems more sustainable and profitable by properly utilizing resources that are inputted into these systems, reducing their overall impact on the environment (Leclère et al., 2020; Teferra, 2022).

Causes of postharvest losses of fruits and vegetable

The main factors of postharvest food losses and waste in sub-Saharan Africa are associated with technical, financial, and managerial limitations in harvesting techniques, storage and cooling facilities in difficult climatic conditions, infrastructure, packaging, and marketing systems (Kiaya, 2014 & Banjaw, 2017).

Kaminski and Christiaensen (2014) estimated that PHL leads to the loss of approximately 37% of food produced in Sub-Saharian Africa. Because they are easily spoiled and considering the lack of specialized facilities for their storage and handling, most fruit and vegetable losses in Sub-Saharian Africa occur before consumption (Tapsoba et al., 2022).

Physical and quality losses of fruits and vegetables are mainly due to poor temperature management, use of poor-quality packages if any, rough handling, lack of or limited market access, and a general lack of education regarding the need for maintaining the quality and safety of perishables at the producer, wholesaler, and retailer levels (Kitinoja et al., 2011; Kaminski & Christiaensen, 2014; Hailu, et al., 2015;). Increasingly, climate change is also a significant contributor to PHL, exacerbating the other factor mentioned (Curzi et al., 2022).

Improper storage facilities in developing countries are one of the leading causes of postharvest losses (FAO, 2013). The International Refrigeration Institute (IIR) calculated that 23% of the perishable foods in developing countries were spoiled because of not being placed in coolers (IIR, 2009). According to (Elik et al., 2019), transportation is also one of the leading causes of postharvest losses, especially for fruits and vegetables, because it places a particular time between production and consumption, and the condition during transport is not ideal for the products. In developing countries, the absence of proper means of transportation, poor roads, and inefficient logistics management prevent perishable foods from being adequately preserved (Elik et al., 2019). In addition, most of the loading and unloading of goods is carried out by unskilled and uneducated workers in these countries, who generally do not carry products carefully. This causes mechanical damage to agricultural products (Azabağaoğlu, 2018).

In open markets or retail, fresh produce is sold in an unpackaged form or tied in a bag. This type of handling can dramatically reduce the product's shelf life if it is not sold quickly (Kiaya, 2014). Packaging is an essential factor in reducing losses and extending the shelf life of fresh fruits and vegetables (Elik et al., 2019). Therefore, one of the key reasons fruits and vegetables are lost at postharvest stages is improper packaging and the use of inappropriate packaging material. The quality of the packaging materials can either adequately protect the fresh produce from damage or accelerate the spoilage of fresh produce.

Tackling PHL improves food security by increasing availability, access, utilization, and stability (Sheahan & Barrett, 2017; FAO, 2021). Addressing PHL is critical to improving food security, addressing issues of malnutrition, and making agricultural systems more sustainable and profitable (Affognon et al., 2015; Stathers et al., 2020; Stathers et al., 2021).

CHAPTER 3: CASE STUDY EVALUATION

I use the program evaluation approach in this section to access four projects addressing food loss in developing countries. Considering that this evaluation was done to inform the design of a framework, it should be seen as supporting a formative purpose rather than a summative purpose. Hence, no judgment about the effectiveness of these projects is drawn from this exercise.

I: The Lost Food Project

Focus of intervention: Rescuing lost food by redistributing them to charities

Location: Malaysia

Website: **Home - Lost Food Project (thelostfoodproject.org)**

The Lost Food Project (TLFP) is a not-for-profit organization in Malaysia seeking to reduce food wastage problems. They sought to address this problem by rescuing lost or surplus food quality from retailers and donors before it goes to waste and is sent to landfills by redistributing them to charities and soup kitchens as well as numerous communities that live in abject poverty. The organization relies solely on its partners and corporate and public donors to help mobilize and sustain them to feed the hungry, not the landfill. These donations fuel TLFP's work immediately and for the long term.

There is evidence of participation. This can be seen through the project team's engagement with its staff, partners, donors, and volunteers based on their recognition and involvement in the project. While engagement with the stakeholders can be seen as a proxy for citizens' participation, this does not fit neatly on Arnstein's "ladder (1969), although one could argue that there is a partnership as developing a shared vision through the project means that power is being shared with citizens since

strategies designed are informed by experiments undertaken by the team during the project. There also seems to be some level of participation between the charities and organizations because they both work closely, though it is a one-sided approach. For example, the organization redistributes surplus food and donates them to charities. Finally, the fact that the food heroes (the founder, staff, volunteers, partners, food and financial donors) are considered the organization's backbone shows that there is a level of collaboration and participation within the organization as they all work together to eliminate hunger in Malaysia. This initiative also means they are willing to listen to diverse ideas, which can be interpreted as allowing for trade-offs.

Methodological Design and Evaluation: The diagram below describes the methodological design of the project in a circular motion. It clearly explains the process of the intervention, showing the various stages at which actions are taken to reduce the loss of food.

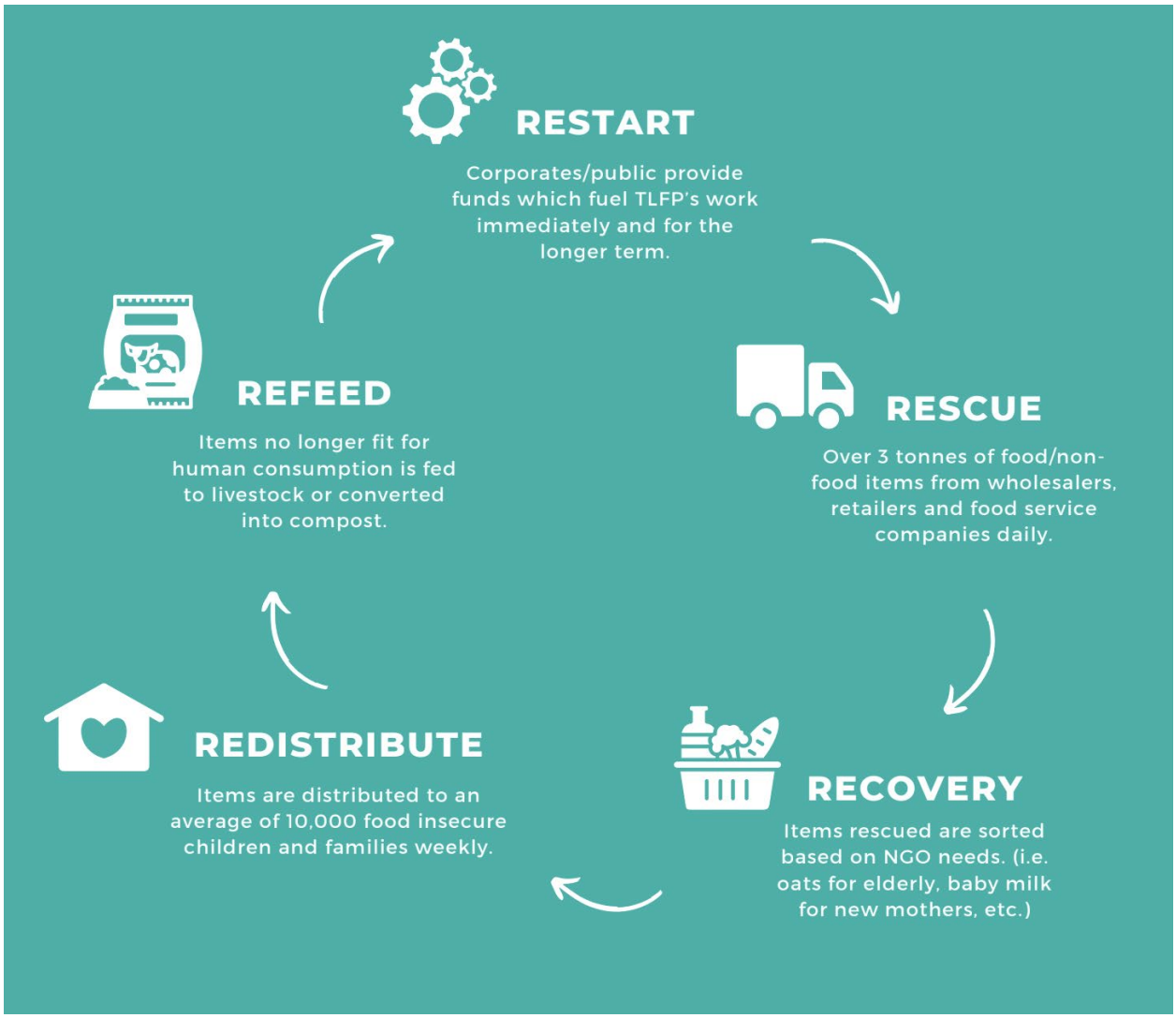

Figure 1: Project Design (Source:*https://www.thelostfoodproject.org/*)

The following are the types of evaluations that were used for this project:

The project used economic evaluation to understand the cost-effectiveness of the various methods put in place to reduce food waste (CDC, 2007). This was important as the economic reason for doing a business (i.e., making profits) is one of the most crucial factors when considering the adoption of a particular practice. The economic evaluation allowed them to collect the relevant data to make the business case and ultimately drive behavior change. Notably, the economic

evaluation will allow them to make a profit to cost analysis and get a clear idea of the financial feasibility of implementing this approach (Chen et al., 2021).

Additionally, the project used impact evaluation to understand how the program affected diversion rate, i.e., the proportion of food prevented from ending in landfills. The impact evaluation helped the project team understand the causal chain's effectiveness from inputs to outcomes (White, 2009). The evaluation was primarily achieved through a full impact report on food wastage which provided a good indication of the program's effectiveness in preventing waste. Notably, the evaluation helped to distinguish between avoidable and unavoidable waste streams (Omolayo et al., 2021), thus helping to streamline the approach to managing food loss. It is unclear how often this was done, but an annual audit would have been the minimum.

Furthermore, the project could have used process evaluation at the beginning of implementation, ensuring a breakdown of the implementation processes (Hulscher et al., 2003), thus increasing the likelihood of project implementation challenges being detected early and resolved promptly. Additionally, this would have given more clarity to the end-of-project assessment (Linnan & Steckler, 2002; CDC, 2007).

Examining indicators and measurements

This chart from the 2021 Impact Report shows the strategies adopted, tools used to advance those strategies, and outcomes linked to the intervention.

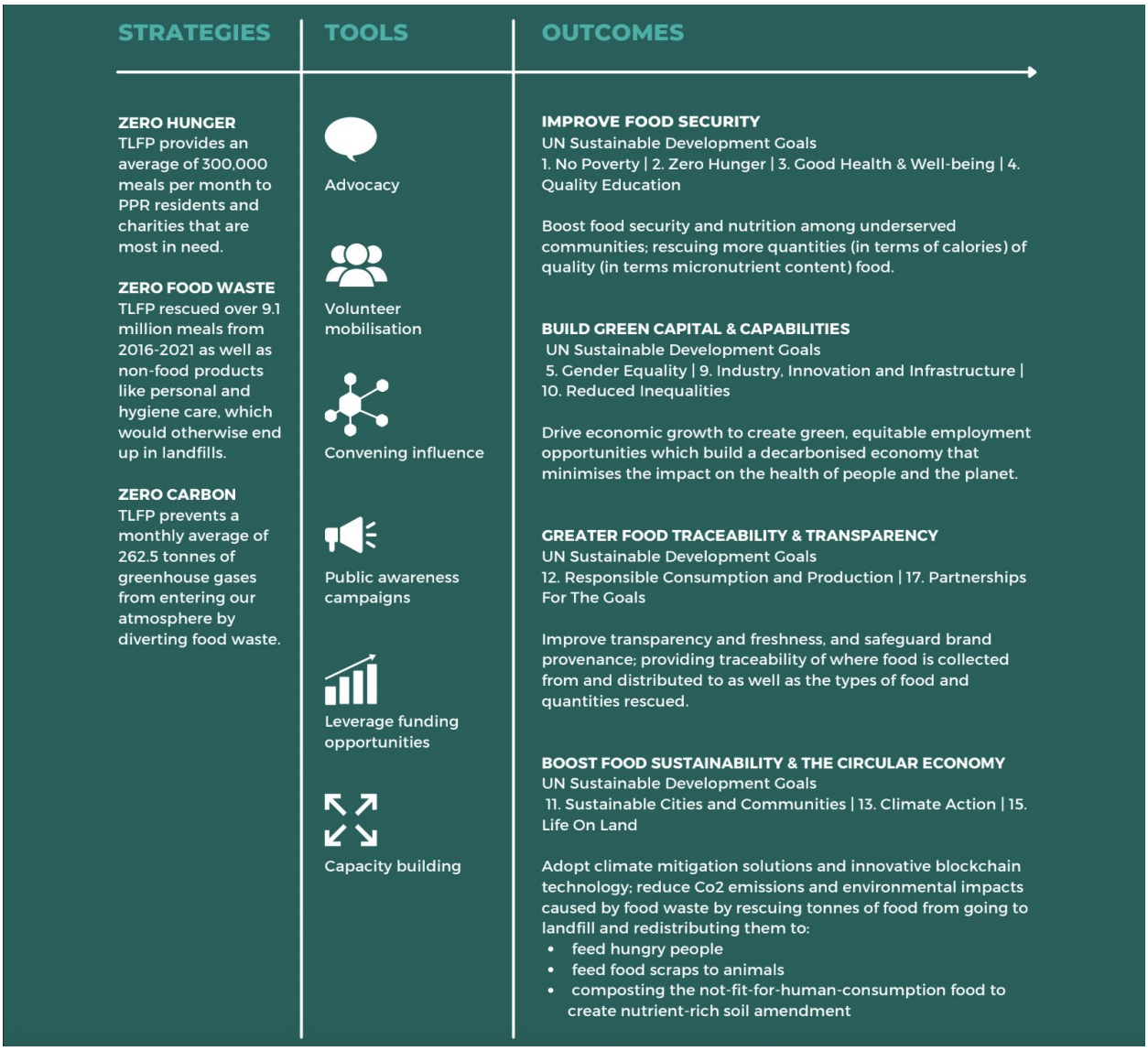

Figure 2: Strategies, tools, and Outcomes (Source:*https://www.thelostfoodproject.org/*)

Key takeaway

- The loss food project works with its public and corporate partners to use excess food to feed the hungry and not the landfill.
- They use their platform to raise awareness and build support.
- The public is also allowed to volunteer.

- The organization isn't limited to fresh fruits and vegetables but rescues other materials to be redistributed to people in need.
- Over 69% of their expenses go to food procurement, and their highest revenue comes from the public sector.
- A partnership is essential to achieving food security.

II. WFP Post Harvest Loss Venture

Focus of intervention: Sustainable PHL business models to enhance food security and income for smallholder farmers

Location: Mozambique, South Sudan, Zambia, and Rwanda

Website: https://innovation.wfp.org/project/wfp-phl-venture

The number of smallholder farmers in Sub-Saharan Africa adopting postharvest loss technologies is low. This causes about 40% of the food produced to waste along the food chain. WFP launched the PHL venture to help solve this problem by executing new business models to make postharvest loss technologies and services accessible and affordable for farmers while ensuring commercial viability for value chain and supply chain actors. To achieve this goal, WFP started working with 125,000 smallholder farmers in 20020 and set up foundations in four developing countries while cooperation with its public- and private-sector partners and local governments. The project has a total of 625,000 beneficiaries, including women and children, and intends to scale up and become mainstream in WFP by 2024.

Methodological Design and Evaluation: The diagram below describes the methodological design of the project in a circular motion. It clearly explains the process of the intervention, showing the various stages at which actions are taken to reduce the loss of food.

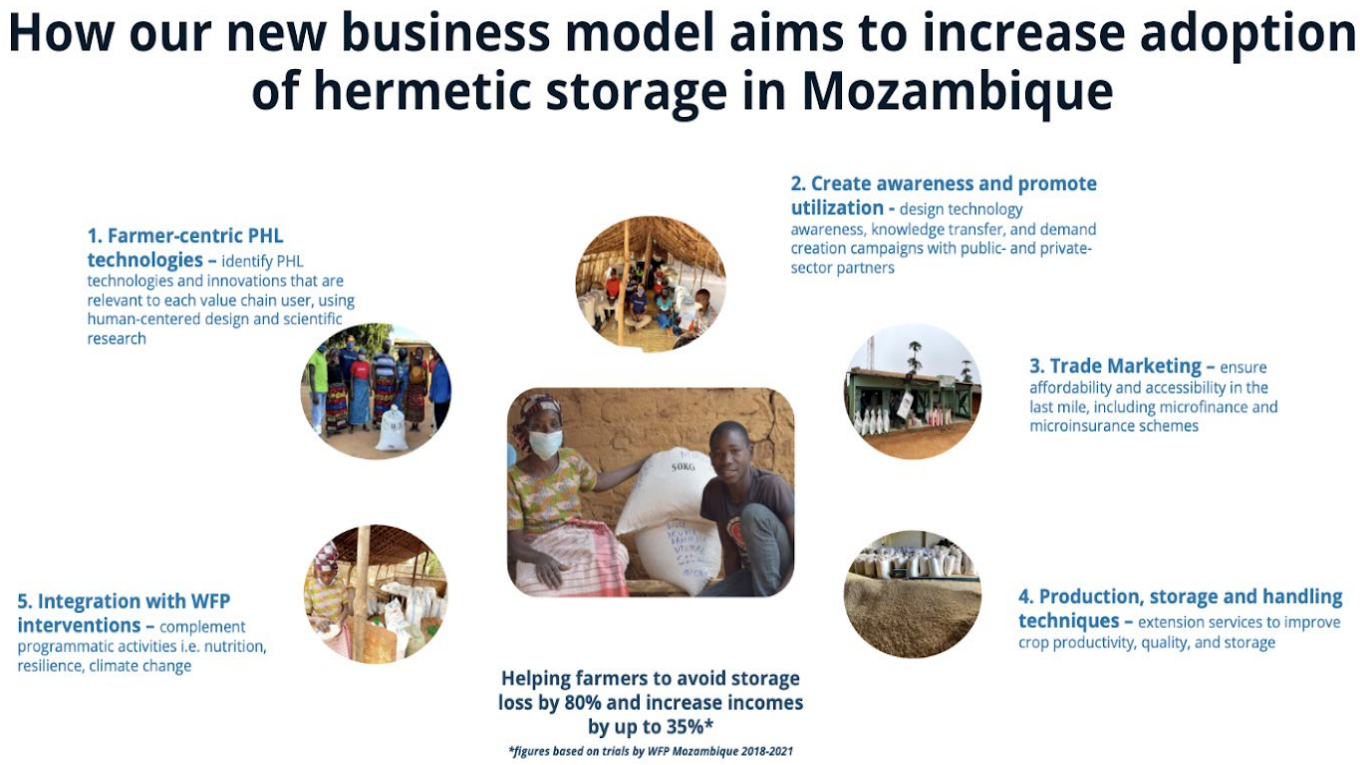

Figure 3: Business Model for Hermetic Storage in Mozambique (Source: *https://innovation.wfp.org/project/wfp-phl-venture*)

The PHL intervention introduced hermetic bags to farmers to replace their raffia bags, thus reducing storage losses at the household level. Demonstrations with targeted farmers showed that hermetic bags are more cost-effective and straightforward to use. Through the demonstration, the farmers show interest and willingness to adopt the technology. Like the previous case study,

process evaluation could have been used at the beginning of implementation to ensure a breakdown of the implementation processes (Hulscher et al., 2003). However, the project was a success because farmers could avoid storage loss at the end of the intervention, and WFP and its partners found a practical solution to the adoption problems faced in countries selected for the trial. This shows that both outcome and impact evaluation were used because of the degree to which the program is affecting the target population's behaviors (CDC, 2007).

The impact evaluation helped the project team to understand the project's success or failure. Importantly, it helped to determine if and how well an intervention worked to create a change in a particular community or country of interest or the lives of its target populations while demonstrating the extent of the impact and how it came about, Rogers (2014).

Key takeaways

- Research and data collection are essential as they help you understand the scale of the problem.
- Scale-up is crucial in innovating new technologies and transforming development projects and sectors. It enhances the application, new concepts, new business models, and diffusion of innovations and practices within and across countries and organizations.
- Awareness raising was highly recommended during this project because one of the project's aims was behavior change. The more people understand the problem and objective of the project, the more willing they will be to participate and subsequently adopt the new technology introduced.
- It is important to design technologies in a local context

- Knowledge transfer is one of the easiest ways to communicate information in a given setting. Educate and train a target ordinance who, in turn, can teach their peers and colleagues.
- Evaluation is vital for development projects. It is a means to track progress and failure throughout the project. They can be used as a learning curve for upcoming projects.
- One of the proven PHL technologies in this case study is the hermetic bag, which can help reduce storage losses dramatically at the household and market levels compared to commonly used raffia bags.

III. Postharvest Management in Sub-Saharan Africa

Focus of intervention: Increase food security of smallholder farmers through reduced PHL

Location: Sub-Saharan Africa focusing on Benin and Mozambique

Website:https://www.helvetas.org/en/switzerland/what-we-do/how-we-work/our-projects/global/postharvest-management-sub-saharan-africa

Helvetas is a development organization that believes all men and women should have equal access to food and clean drinking water. The organization is committed to changing the lives of disadvantaged people in Africa, Asia, Latin America, and Eastern Europe. The organization is also active in tackling problems associated with climate change. They are based in Switzerland with affiliated organizations in Germany and the United States.

During the Postharvest Management project, which lasted from 2012 to 2020 in sub-Saharan Africa, Helvetas sought to address problems associated with postharvest losses and to increase the food security of smallholder farmers at the farm, community, and market levels.

The two strategies used by Helvetas are to ensure that households and communities have a regular food supply through improved postharvest management and that they can have commercial income generation through improved food quality and market access.

Methodological Design and Evaluation

The website does not explain the methodological design used during the intervention or did they talk about evaluation. Instead, the project listed a couple of interventions it made on its target population and communities.

The list of projects intervention includes:

- Good postharvest practices and technologies were validated on-farm with support from local research institutes, including harvesting, threshing, drying, and storage.
- Practiced tests were documented, tools disseminated, and methodologies developed.
- The program enabled market partnerships between traders, buyers, and producers of new postharvest technologies such as hermetic bags to boost innovation in local markets.
- From the field evidence, dialogues and campaigns were conducted at the local, national, and regional levels to include postharvest management in policies and regulatory frameworks.

Main achievements of the project

- 11,106 small farmer households have reduced food loss by adopting effective postharvest management practices with an average additional income of 200-250 USD per year.
- Thirteen producer groups in Benin adopted a collective food storage scheme, enhancing their access to markets, food quality, and long-term food security.

- New market innovation was introduced (hermetic storage bag technologies) in Northern Mozambique. As demand from farmers increased, various distribution locations and networks were established by local agro-retailers to sell the new technologies.
- Postharvest management has been integrated into training courses for all 12 agricultural technical schools in Benin countrywide and nine agricultural schools and universities in Mozambique as mandatory expertise.
- Both countries' governments commit to new policies on food loss reduction and postharvest management.
- Postharvest management is today an integral part of regional policy discourses in Sub-Saharan Africa and has entered regional extension services networks as crucial expertise.

Key Takeaway

- Collective food storage schemes
- New hermetic storage technologies
- Governments committing to new postharvest management policies
- Facilitate market participation between producers, traders, and buyers

IV: Fenik Cool Box

Focus of intervention: Longer shelf life for better nutrition and increased food security

Location: Malawi

Website:https://innovation.wfp.org/project/fenik-cool-box

This pilot project seeks to support rural smallholder farmers by increasing the shelf life of homegrown fruits and vegetables in the Southern Region of Malawi. Its focus is to ensure better dietary diversity and indirectly increase farmers' income by saving on costs.

According to Katengeza (2011), the major problem faced in this region is limited access to electricity and cold-chain storage solutions for perishable crops. This problem is a crucial constraint to increasing the utilization of fruits and vegetables by smallholder farmers and their families in rural Malawi. Furthermore, with chronic malnutrition at 37.1 percent, looking at solutions to increase the availability and utilization of nutritious food is a crucial bottleneck that needs to be addressed (Bartels, 2016).

The cooler uses sophisticated engineering on a simple concept of evaporation to increase the shelf-life of perishables. In addition, the six-liter (6L) capacity cooler is entirely off the grid, relying exclusively on the water for functioning. This innovative idea of a simple measure to improve small-scale cold chains is a first for Malawi. It will provide a new opportunity to turn increased shelf-life directly and indirectly into increased income for families (both from preserving homegrown food rather than purchasing and providing longer time for selling surplus) and increase the availability of nutritious food.

CHAPTER 4: CONCEPTUAL FRAMEWORK TO REDUCE POSTHARVEST LOSS IN LIBERIA

The causes of PHL are complex and multi-faceted, requiring a systematic approach if one must tackle it. Importantly, these issues arise because of the actions of multiple actors across the supply chain, acting within the limitation of the current infrastructure system. This means solutions require cooperation and partnership supported by the government, small businesses and marketers, local farmers, relevant NGOs, and private sector companies.

The design of a conceptual framework can be seen as the initial step toward the formulation of a national strategy to address PHL. However, this framework is not grounded in field research, so it can be seen as a roadmap toward developing a national strategy. Furthermore, the underpinning analysis has been undertaken exclusively from literature review and, therefore, requires piloting of the proposed solutions to quantify better the socio-ecological and economic costs associated with tackling PHL across Liberia. Finally, the framework emphasizes partnerships as the primary means to deliver change, but policy development will be equally important to facilitate these partnerships and enhance interventions outlined under the framework.

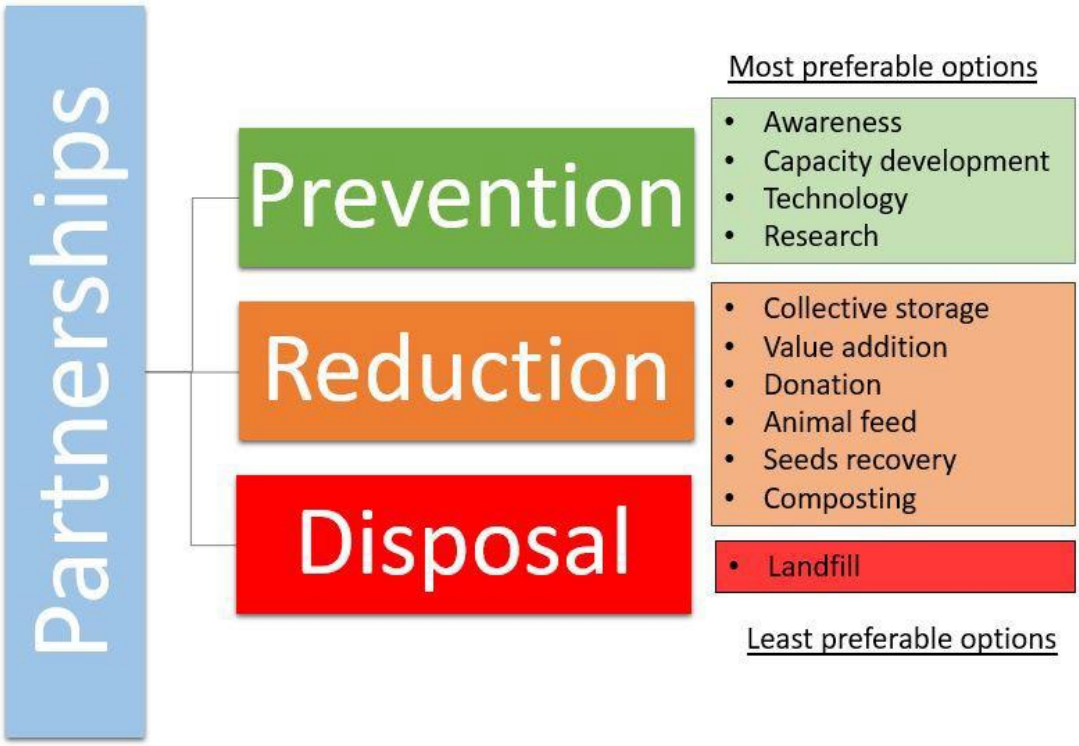

Figure 4: Conceptual model of a PHL mitigation framework for Liberia

Ultimately, addressing PHL in Liberia should focus on improving efficiency along the supply chain - on the farm, transportation, distribution, and at the market. In most instances, consumers use food efficiently, eating what they buy. Therefore, implementing the five steps below will be necessary for operationalizing the conceptual model above and provide a framework that can be used to address PHL in Liberia.

Step 1: Setting the National Context: Field research is necessary to collect data to quantify the scale of food loss and waste in Liberia. The foundational step in addressing PHL is to build a case for considering it as an essential issue in the first place. This involves quantifying the volume of PHL, determining the socio-ecological, health, and economic costs that can be linked to PHL, and identifying the relevant legal and institutional frameworks and associated gaps relating to PHL

Understanding the scale of the problem and getting a holistic view of PHL in Liberia will determine the severity of the issue and the level of urgency that needs to be given to addressing it. Finally, through a cost-benefit analysis, the research will determine the extent of PHL, showing its link to other issues negatively impacting society. For example, establishing a causal link between PHL and disease like malaria and typhoid that has a heavy toll on the country's healthcare system will demonstrate the need to address this issue urgently

Step 2: Understanding Causes and Impact: Identify the primary sources of PHL in Liberia, focusing on the most significant sectors and their underlying causes. Most times, the waste we see in markets is what brings to our attention the scale of the problem associated with PHL. However, considering this loss is happening along the supply chain, it will be essential to investigate and understand the root causes as the most effective interventions to address the problem at the source. Relatedly, it will be necessary to determine and show the social, environmental, and economic dimensions and costs of PHL. This could be achieved through comprehensive nationwide qualitative and quantitative research with a team of scientists and researchers in collaboration with the Liberia Institute of Statistics and Geo-Information Service (LISGIS), the Ministry of Agriculture (MoA), the Environmental Protection Agency, and external partners such as WFP, FAO, World Bank, and USAID on the cause, effect, and impact of PHL in Liberia. Additionally, to deal with the cost associated with a large team, 'citizen scientists' could be incorporated to record and report data through the development of an app that will allow them to contribute to the reporting incidences of PHL they will encounter. Finally, the survey can be complimented by structured focal group discussions in the rural and urban areas that will be able to bring out additional issues relevant to PHL.

Step 3: Identifying the Relevant Legal and Institutional Frameworks: It will be necessary to evaluate Liberia's current legal and institutional frameworks to understand the levers and obstacles to addressing PHL. This legal and institutional analysis will inform the subsequent steps needed to operationalize a strategy for addressing PHL. For example, there is currently no guideline about converting food to animal feed, which acts as a bottleneck for investment in that sector. Another issue relates to the lack of an incentive (e.g., tax break) to promote value addition that will prevent PHL. Finally, without the institutional arrangement that encourages collaboration between various government agencies to address this issue, it becomes difficult to implement programs that will address this problem. For example, a partnership between the Liberia National Investment Commission, the Ministry of Agriculture, and the Environmental Protection Agency could bring the necessary investment and collaboration to address this issue.

Step 4: Action Planning and Visioning: Through a participatory process that involves actors at all spectrums of the supply chain, map out the potential solutions to addressing PHL, proposing clear actions that can be implemented in the short, medium, and long-term by various stakeholder groups. Setting these time-bound goals will be helpful to access the effectiveness of the program of work outlined to address PHL. Importantly, this will allow for reassessment and realignment in addressing the issue. An important aspect of this visioning process will be the design of the financing plan needed to operationalize planned interventions that will be developed from the proposed mitigation hierarchy.

Step 5: Monitoring, Evaluation, and Learning: Use findings from the structured monitoring of pilot interventions to iterate within an adaptive management framework, sharing learning at various stages of intervention. The monitoring, evaluation, and learning framework will be the tool through which objective conclusions can be drawn about the effectiveness of interventions to

tackle PHL. Therefore, it will be important that indicators in the framework are specific, measurable, achievable, realistic, and time-bound (SMART). With this SMART tracking system, lessons on what worked and did not work can be documented and inform program implementation.

CHAPTER 5: CONCLUSION

A circular economy concept aims to overcome the linear pattern of "take-make-dispose" by adopting circular strategies of "closing the loop." Most importantly, it promotes sustainable and resource-efficient policies and actions for long-term socioeconomic and environmental benefits. There is a consensus that reducing FLW has excellent potential for enhancing food security, strengthening the sustainability of food systems, and avoiding economic costs along with the FSC. Also, there are substantial gaps in knowledge and research about FLW required to bring about this change. Despite the scale of the problem, the lack of reliable and consistent data and inconsistencies in definitions and measurement frameworks of FLW need to be addressed if FLW reduction strategies and solutions are to be effectively assessed and compared. Although this is a critical issue for decision-makers, the review focuses on the lack of information and assessment of the socioeconomic impact of various policies and measures to reduce PHL in the literature. More holistic approaches and strategies need to be introduced to lead future research to tackle PHL as part of the circular economy. And particularly on the socioeconomic and environmental impacts of PHL reduction strategies across the food supply chain stages in different regions and development contexts—including agriculture systems, available infrastructure, energy needs, and current marketing network.

There is a need to focus on adopting integrated approaches designed to reduce food loss and waste. Actions are required globally and locally to maximize the proper use of the food we produce. Introducing sustainable technologies, innovative solutions, new ways of working, and good practices to manage food quality and reduce food loss and waste is essential to implementing this transformative change FAO (2015).

Ultimately, methods that reduce GHG emissions while improving food security and increasing local capacities to adapt to climate change depend on the development and uptake of sustainable technologies along the entire value chain, particularly in postharvest operations and during processing and storage. In addition, developing systems that reward a circular and environmentally friendly food system could also lead to more sustainable practices. One of the most obvious benefits of reducing FLW is that it will increase food availability, contribute to poverty alleviation efforts, and improve millions of people's well-being, with all these benefits for society.

Tackling food losses and waste in an efficient, sustainable, and integrated way should be seen as an opportunity to feed people and optimize the use of natural resources simultaneously (Rezaei et al., 2017). The private sector, including the food industry, can play an essential and unique role in food loss and waste reduction by optimizing food processing procedures, streamlining supply chains, and linking farmers to markets, among other things (Rezaei et al., 2017). Effective responses to FLW will ultimately require complementary approaches and robust evaluation utilizing an adaptive management framework, with feedback leading to various iterations.

The most obvious benefit of reducing FLW is that it will increase food availability and the income of local farmers, thus contributing to poverty alleviation efforts with all the benefits it provides for society. With a view to the future, it makes sense to address FLW as it represents a unique opportunity to address a societal problem and contribute to protecting the natural world.

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