Economic Sustainability of Post-Harvest-Investments – Analyses from the Green Innovation Centers

Investigating technical measures to mitigate post-harvest losses and recommendations for sustainable business models

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Green innovation centres

GFA CONSULTING GROUP

Contents

Abbreviations

APHLIS	African Postharvest Losses Information System
BC	Business Case
BMZ	German Federal Ministry for Economic Cooperation and Development
CaaS	Cooling as a Service
CEEC	Citizen Economic Empowerment Commission
CP	Country Package
EUR	Euro
FCFA	West African Franc
GEM	Grain Quality Enhancement Machine
GIC	Green Innovation Centers for the Agriculture and Food Sector
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
HP	Himachal Pradesh
iDPP	integrated Development Partnerships with the Private sector
INP HB	Institut National Polytechnique Félix Houphouët-Boigny
IRR	Internal Rate of Return
KPI	Key Performance Indicators
MK	Malawi Kachawa
MT	Metric ton
NGO	Non-Governmental Organization
NPV	Net Present Value
OCOP	One Commune One Product Program
PHL	Post-Harvest Loss
VC	Value Chain
VIETGAP	Vietnamese Good Agricultural Practices Program
VND	Vietnamese Dong
ZMW	Zambian Kwacha

Executive Summary

Global food waste is a significant problem, with approximately one-third of total food production wasted, and 14% lost during post-harvest and retail stages. At the same time, high levels of hunger persist, affecting nearly 828 million people worldwide (World Food Program 2021). Efforts to reduce PHL (PHL) present an opportunity to enhance food security by improving smallholder farmers' livelihoods, increasing the availability of nutritious crops, and promoting efficient resource utilization.

The Federal Ministry for Economic Cooperation and Development cooperation (BMZ) allocated additional EUR 5 million to the Global Project "Green Innovation Centers for the Food and Agriculture Sector" (GIC) to intensify measures to combat PHL. In this context, a study on the economic sustainability of post-harvest investments has been conducted in June 2023.

The objective of this study is to provide an objective and economically differentiated analysis of investments targeting PHL in the selected partner countries. It covers the entire downstream value chain (VC), including harvest, sorting, storage, transport, and processing of agricultural products. By identifying critical loss points and assessing the economic effectiveness and sustainability of investments, the study gages the measures and makes recommendations to achieve the most impactful outcomes.

The study considers key quantitative economic parameters, such as investment costs, running costs, opportunity costs, price impact, marketable quantity/reduced crop loss, and income generation. Additionally, it recognizes the significance of framework conditions, including financing availability, key services, infrastructure, legal aspects, agricultural policies and the local economic context. Although the study acknowledges its limited scope and timeframe, it considers socio-economic factors during investigations and provides recommendations for sustainable business models. For 4 CP, a general description of the economic sustainability of selected innovations has been done (case studies), 3 further CP received more detailed analyzes and recommendations of their chosen PHL innovations (business cases).

The quantity and quality of economic data available at the Country Package (CP) level varies due to differences in implementation stages. Some CPs have successfully introduced technical innovations and collected data, while others are still in the capacity-building phase. A comprehensive economic analysis of profitability is therefore not possible for all CPs. There are also significant differences in the technical nature of measures, target groups, business models and VCs across CPs. A generic comparison of the economic profitability of these measures would not capture the complexity and diverse goals of the GIC's efforts.

Case Studies

The CP **Burkina Faso** promotes a locally produced multifunctional thresher that can process multiple crops, including **rice,** maize and sorghum. The thresher is a mobile autonomous machine that is moved from field to field to thresh the freshly harvested rice of small-scale rice producers. As the time the harvested crops stay on the field is reduced compared to traditional manual threshing, the rice is less prone to attacks by pests. In addition, the product is cleaner and the amount of broken grains is reduced to nearly zero. The direct beneficiaries are young entrepreneurs who are trained to use the machines and then offer threshing services to smallholders. This approach allows farmers to cope with labor shortages that occur around harvest time.

The intervention in Burkina Faso has been successful, empowering young entrepreneurs to establish lucrative enterprises while effectively mitigating PHL for rural rice producers. The functionality and value proposition of this technology, coupled with the presence of a pre-existing market, lay a strong groundwork for the intervention's prospective expansion and enduring influence.

The CP **Côte d'Ivoire** promotes locally produced solar-powered dryers for **cassava** chip drying in flour production, which serves the dual purpose of reducing PHL and creating new market opportunities for cooperatives. The conventional method of sun-drying exposes cassava chips to various risks such as weather, dust, animals, and mold growth, particularly in the face of unpredictable rainfall patterns. As women predominantly handle cassava harvesting and processing, this intervention primarily benefits them, supporting their income-generating activities.

To attain profitability, it is imperative for cooperative members to produce cassava roots at a price that is highly competitive, considering that the added value from the drying process must offset the required investment and anticipated operational expenses. However, the business analysis exposes a notable deficit attributable to the substantial costs linked to skilled personnel managing the "to-be" piloted solar drying units. Coupled with the raw material costs, this combination could potentially render the business model unprofitable.

The CP **Malawi** also focuses on supporting women cooperatives engaged in **cassava** cultivation and processing. The project provides essential equipment such as graters, grinders, baking structures and solar dryers. The groups are trained to produce and maintain the dryers themselves for sustainability purposes.

Access to suitable financial products with reasonable interest rates will be essential to ensure the scalability of this intervention. The development of a comprehensive business plan based on data gathered during the test phase is of utmost importance and should be prioritized in the upcoming months.

The motorcycle milk testing innovation in the CP **Zambia** addresses the challenge of PHL in the **dairy sector** by providing efficient veterinary diagnostic laboratory test services and extension support to smallholder farmers. The intervention involves equipping cooperatives with motorcycles for timely sample delivery to a newly established provincial veterinary diagnostic laboratory.

The approach facilitates cooperative members' quick access to a new milk testing facility in Zambia's Southern Province, enabling them to determine milk quality, reduce rejection rates, and enhance bargaining power for price premiums. By reducing PHL due to milk rejection by off-takers, the intervention has the potential to enhance the profitability and income of small-scale dairy farmers and cooperatives. The sustainability of this service also relies on developing a concrete business plan, calculating operational costs, optimizing logistics, and exploring partnerships for funding.

Detailed Business Cases

In the CP **India**, climate-intelligent cold storages have been implemented in the **apple VC** at the smallholder level. By utilizing solar-powered technology, this intervention aims to provide affordable access to energy-efficient post-harvest technologies and practices, such as cooling and precooling while additionally improving sorting, and grading. The initiative targets farmers in the state of Himachal Pradesh, who currently lack access to near-farm infrastructure and rely on private or large corporate owned controlled-atmosphere stores. The implementation of the GIC cold storage facilities offers producers a reliable market by enabling off-season sales at higher prices and reducing the risk of spoilage. The cold storage facilities are provided under a "Cooling as a Service" (CaaS) model. A third-party provider owns and operates the infrastructure and charges farmers a fee for its usage, providing smallholder farmers access to cooling technologies without the need for upfront investment.

The cold storage intervention holds great potential for scaling up and replication, benefiting both PHL and greenhouse gas emissions reduction. However, additional resources and stakeholder involvement along with a blended finance business model are needed to achieve sustainable and inclusive economic growth. Collaboration among farmer cooperatives, government agencies, financial institutions, and private sector partners is crucial. Recommendations include the developing a viable business model with attractive pricing strategies and payment terms, assessing crop mix and production to ensure full capacity utilization, establishing a funding strategy involving various sources, implementing a maintenance plan for efficient operation, fostering partnerships with relevant organizations, prioritizing training and capacity building to ensure effective utilization, and establish strong business models.

The de-sapping and hot water treatment innovation in the CP **Vietnam mango VC** involves removing the sap or gum from mango fruits through soaking them in a hot water solution. This results in cleaner and visually more appealing fruits. Additionally, the hot water treatment eliminates pests and insects, meeting phytosanitary standards and extending the shelf life of mangoes.

Critical aspects of this innovation include the need for dedicated physical infrastructure such as treatment tanks and heating systems, advanced technology for effective monitoring and management, a skilled workforce for proper handling, and reliable transportation and logistics. By improving fruit quality, addressing key phytosanitary compliance challenges, and meeting market demand, this innovation has the potential to enhance the economic sustainability and competitiveness of smallholder cooperatives and expand their access to broader domestic and international markets. Investing in the de-sapping and hot water treatment innovation holds great potential for combating PHL and generating revenue for cooperatives and associated farmers. Successful implementation relies on collaboration and partnerships with mango farmers, equipment suppliers, retailers, and government agencies, emphasizing the importance of building strong relationships and effective communication channels. A comprehensive market analysis is essential to ensure economic sustainability. This will allow for targeted marketing efforts, efficient production planning, and competitive pricing strategies to capture a significant share of the domestic urban market. Recommendations include: Optimizing capacity utilization, developing a financing strategy, conducting market research, offering value-added services, fostering supply chain collaborations, and investing in farmer capacity building.

The CP **Mali** addresses PHL and improves rice quality by implementing an energy-efficient **rice** parboiling technique known as the Grain Quality Enhancement Machine (GEM). This innovative method utilizes rice husks, a byproduct of the rice hulling process, as a sustainable fuel source to heat the GEM stove. The project supports women-led rice processing cooperatives in piloting the locally produced stoves.

Sufficient capital is required to finance the various component of the integrated processing plant, such as a paddy soaking tank, a rice husker, and cemented floors for enhanced drying surfaces. Ideally, a significant storage facility is available to store rice acquired at low prices during the harvest season to ensure year-round operation of the parboiling facility. Acquiring sufficient paddy rice on an annual basis is therefore also a critical recurring operational cost. The study shows that the GEM outperforms other parboiling methods, by offering greater efficiency, improved rice quality and uniformity, and reduced labor requirements – thus making it a viable investment option for cooperatives if financing is possible. However, the validity of our analysis relies on certain underlying assumptions that require confirmation during the on-going pilot program. First, it is essential to ensure a steady supply of paddy rice at a viable price. Second, the willingness of consumers to pay price premiums for domestically produced parboiled rice must be assessed. If consumers are not willing to pay premiums similar to those for imported parboiled rice, the economic viability of the GEM may be compromised. Finally, the availability of dynamic financial products is essential to cover the high investment costs associated with implementing the GEM, as well as ongoing running costs such as acquiring large volumes of paddy rice. Cooperatives need suitable financial products tailored to their specific needs to ensure the project's financial sustainability. If the above critical components can be assured, a solid foundation for sustainable economic business case can be made.

Conclusion

The examined measures demonstrate promising outcomes in addressing economically significant PHL faced by smallholder farmers globally. These innovative approaches, conceptualized and piloted by different teams within a short timeframe, show potential for improvement in tackling this persistent challenge. All of the introduced measures address relevant critical loss points by promoting specific technical solutions, but their long-term success depends on embedding them in a comprehensive VC approach. Based on the related challenges faced by the CP's, the study derives the following main recommendations:

- Appropriate financial products are often not available and thereby hinder upscaling. The interest rates for loans are too high and/or pay back periods are not adapted to the business models. Consequently financial institutions have to be provided with field-proven economic data and sound business models, as to encourage them to develop suitable products.
- When promoting innovations, which mainly aim to improve the quality of a product, one must assure there is a willingness of customers to pay premium prices and develop a strategy to access these markets (parboiled rice in Mali / mangos in Vietnam).
- Many technologies require, that large quantities are processed to make the investment profitable. A constant supply at viable prices must be assured (cassava in Côte d'Ivoire & Malawi / paddy rice in Mali). This also applies to processing as a service, where one relies on a large enough customer base to make the business viable (cold storages in India).
- The full labor costs of smallholders have to be accounted for in production and processing, when assessing the economic sustainability of investments. Omitting these costs, may give the false impression that the activity is profitable.
- All CP's have assured, that the technical equipment and tools can be sourced and maintained locally. This is critical for the longevity of the investments as wells as up-scaling and creates business opportunities for local input and service providers.

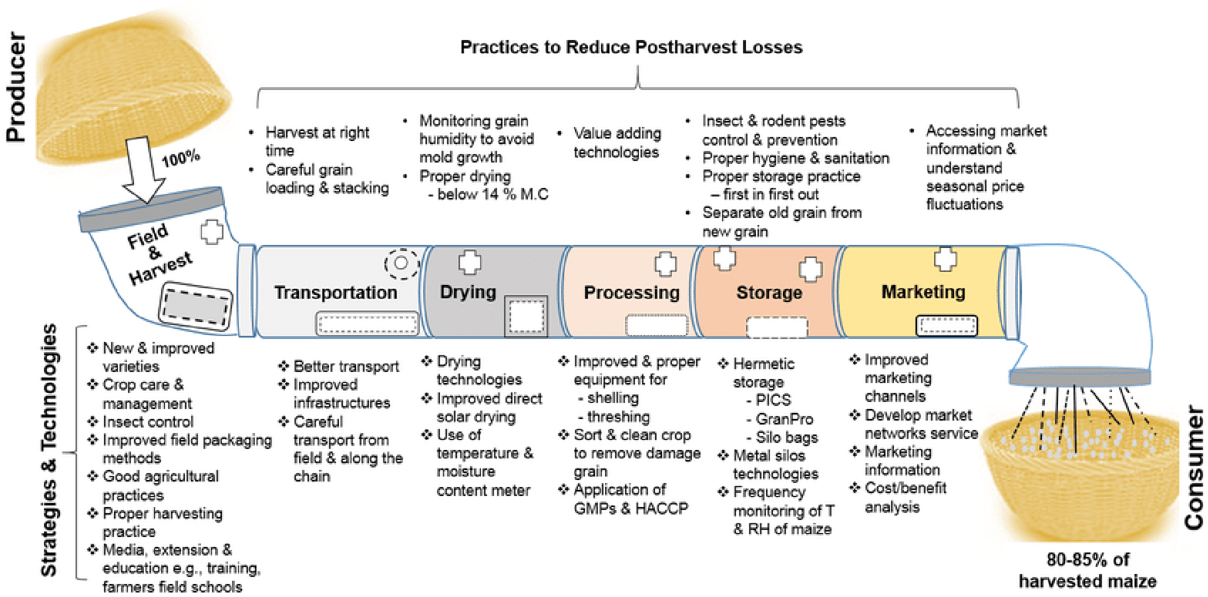
In conclusion, the CPs have a wealth of experience and knowledge beyond the scope of this study. It is therefore recommended that opportunities for knowledge exchange among countries involved in similar technologies or VCs be explored. This collaboration will facilitate the dissemination of valuable insights and expertise, promoting effective solutions and fostering continued progress in combating PHL.

1 Background

Global food waste is estimated at around 1/3 of the total food production, while around 14% of all food produced is lost in the post-harvest stage up to the retail stage (Food and Agricultural Organization 2019). At the same time hunger levels remain high with nearly 924 million people facing severe levels of food insecurity (World Food Program 2021). In India, PHL are estimated at 10%-25% for perishable foods such as milk, fish and eggs and even higher at 30%-40% for fruits and vegetables. In sub-Saharan Africa alone, where over 230 million people suffer from chronic undernourishment, 30-50% of production is lost at various points along the VC.

Efforts to reduce PHL thus provide an attractive opportunity to improve food security. They can have a multi-faceted impact on smallholder farmer livelihoods (by increasing incomes), nutritional security (by improving the availability of relatively nutritious crops) and efficient use of resources (by ensuring that resources such as land and water are used to produce food that is eventually consumed rather than wasted).

Against this background, the German Federal Ministry for Economic Cooperation and Development (BMZ) has provided an additional EUR 5 million to GIZ's Global Program "Green Innovation Centers for the Agriculture and Food Sector" (GIC) to introduce measures to combat PHL, which have been implemented in 8 country packages since April 2021. This study investigates the economic sustainability of these investments and gives recommendations for sustainable business models.



*Suleiman RA, Rosentrater KA. Current maize production, postharvest losses and the risk of mycotoxins contamination in Tanzania. Am Soc Agric Biol Eng 2015;7

2 Objectives

The aim of this study is an objective and economically differentiated analysis of the different investments to mitigate PHL in selected partner countries of the GIC program. The investigated measures cover the entire downstream VC, from harvesting and sorting to storage, transporting and processing of agricultural products. Investments can be made at different points in the post-harvest cycle – by producers themselves, or by suppliers, service providers and processing companies who directly contribute to economic development and value creation in the chain. The study examines selected investments in post-harvest protection in terms of their economic effectiveness and sustainability. To achieve this, first, core elements of economic sustainability in postharvest protection are identified. Then, interventions implemented as part of the PHL Booster are evaluated using a structured questionnaire. The study focuses on the framework conditions, cost-benefit analysis and financing. A business model canvas[1] is also provided for each of the innovations. Special consideration is given to the respective country context and the localization of the individual measures within the VC. For three selected country packages, in-depth analysis are carried out and recommendations for sustainable business models are developed. By exploring sector-specific key performance indicators (KPIs) and applying a comprehensive evaluation methodology, the study aims at enhancing the logical coherence and enables the effective categorization of business cases (BCs).

3 Methodology

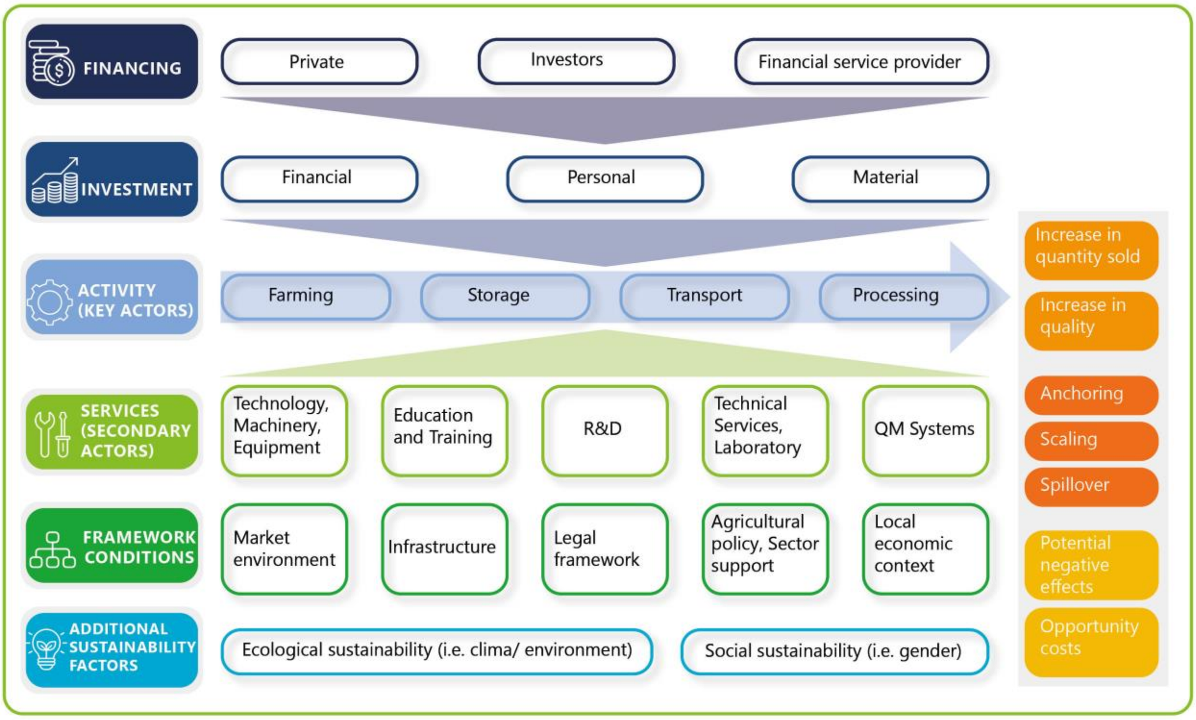
For a meaningful assessment of the economic sustainability of PHL reduction measures the following underlying *quantitative* economic parameters are considered:

- **Investment costs:** Resources required to set up and start implementing the measure. These may be funds necessary to acquire land, facilities or equipment/tools. They also comprise costs to gain knowledge via trainings or networking.
- **Running costs:** Direct material, rent, fuel, electricity, paid labor, operation and maintenance costs
- **Opportunity costs:** Time or resources not available for other economic activities which may be more cost efficient (e.g. increasing cultivation area may be less effort but yield more income than a PHL reduction measure)
- **Price:** The price paid by consumers for agricultural products targeted by PHL prevention methods, is used as an impact indicator. Prices increase due to improved quality and because farmers can wait for better prices instead of directly having to sell their product after harvesting.
- **Marketable quantity/Reduced Crop Loss:** Improvements in handling, transport and storage that lead to less spoilage and loss can result in a higher amount/weight of intact agricultural products
- **Income:** Farmers and other VC actors can benefit from PHL prevention methods through increased income. Income is an indirect indicator resulting from several of the above-mentioned parameters and is therefore useful for assessing the sustainability of measures.

Regardless of the quantitative parameters, the study takes into account that the economic sustainability of the promoted measures is essentially dependent on the framework conditions. These include the availability of financing, key services in the immediate vicinity and institutional framework conditions consisting of infrastructure, legal aspects, relevant agricultural policies as well as the local economic context.

The parameters mentioned and their interrelationships are illustrated in the figure below, which served as the methodological framework for the development of questionnaires and ensuing interviews.

[1] The business model canvas is a strategic management tool that provides a visual framework for describing and analyzing the key elements of a business model. It encompasses nine essential building blocks, including customer segments, value propositions, channels, customer relationships, revenue streams, key activities, key resources, key partnerships, and cost structure.



The in-depth interviews with the three CPs selected to develop the business cases (BC) go into even more detail in order to obtain the necessary information to elaborate the BC according to the following composition:

1. Spatial and factual delimitation of the measure (localization within the VC, spatial establishment, actors and participants)
2. Technical description of the measure
3. Analysis of the relevant sub-market(s) and the market environment (suppliers, customers, competitors, price formation and development)
4. Development of business model canvas describing key elements of the BC
5. Economic classification of the measure (added value) and detailed cost-benefit analysis, Net Present Value (NPV) and Internal-Rate of Return (IRR) (if possible)
6. Critical success factors and Recommendations

The collection and/or calculation of economic data and specific KPIs supports the development and rating of the business cases. When assessing the measures, special attention is paid to the economic integration of smallholders into local/national VCs. During the analysis, the viability of the BCs including factors such as potential side transactions, opportunity costs, potential negative impacts, as well as socio-economic consequences are further considered. To accomplish this, a two-fold approach is adopted. First, the investment options are described using their respective KPIs, allowing the establishment of a comparative framework. Second, potential opportunities, synergies, and conflicting objectives that may arise within the BCs are identified.

4 Overview

Initially, the following country packages and respective booster measures were considered for the study:

Country	VC	Title	Investments	Target Group
Zambia	Peanuts	Aflatoxin prevention through improved peanut processing	- Peeling machines and other processing equipment	Women led co-operatives
Zambia	Milk	Improved monitoring of milk hygiene	- Milk testing equipment and provision of motorcycles	Milk producing cooperatives
Mali	Rice	Improved processing techniques	- Climate intelligent parboiler (GEM): Local maintenance, repair and manufacture of machines	Women led rice processing cooperatives
Burkina Faso	Rice	Improved post-harvest management at farm level	- Mobile multifunctional thresher	Young entrepreneurs (threshing service providers)
Togo	Peanut Cashew Soy	Postharvest in organic farming	- Pasteurization equipment for juice production - Energy-saving ovens for cashew production - Refrigerated bicycles to enable climate-friendly delivery of soy products	Micro, small and medium-sized organic soy producer enterprises
Côte d'Ivoire	Plantain Manioc	Improved processing of raw materials and by-products	- Solar dryers for cassava and plantains - Establishment of a laboratory for local seed production for mushroom production - Establishment of pilot plants for innovations in the processing of by-products from cassava and plantains	Women groups within cooperatives
Cameroon	Potato	Quality management and improved storage practices	- 26 simple and inexpensive seed storage houses - 13 small potato storage houses built from local materials (Diffused Light Store)	Individual small scale producers & cooperatives
India	Potato Apple Tomato	Climate intelligent storage and processing technologies	- Climate smart cold storage (apple and potato) - Tomato dryer	Cold-storage providers

Country	VC	Title	Investments	Target Group
Vietnam	Mango	Improved capacities and standards for increased durability	- De-sapping and hot Water treatment: Pilot projects of the post-harvest center in partnership with supermarket chains - Solar drying of Mango at co-operative level	Mango producer cooperatives

Based on discussions with experts from the CPs and the steering unit during the kick-off and ensuing coordination meetings, as well as the initial responses to the questionnaires, it was decided to drop certain countries/measures. On the contrary, Malawi was added to the list even though the CP did not receive specific funding from the booster, as the CP voiced that a study would provide valuable support during the early stages of introducing a PHL reduction measures.

This resulted in the following final selection of CPs:

Case Studies

Côte d'Ivoire – Cassava

Burkina Faso – Rice

Zambia – Milk

Malawi – Cassava

Business Cases

India – Apple

Vietnam – Mango

Mali – Rice

At the time of the study, for the majority of CPs, the necessary field data were not yet available. Consequently, a thorough economic analysis of the profitability of measures is not possible. Whenever feasible, secondary data from studies or expert opinions are used to develop qualitative scenarios that allowed to draw hypothetical conclusions. Despite obvious shortcomings, these can show potential trends, risks or shortcomings, and help in the future design or roll out of the measure, as well as identify areas for further development and analysis.

5 India – Apple – Cold Storage – Business Case

5.1 Context

The Indian state of Himachal Pradesh (HP) is located in the western Himalayan agro climatic zone and has a wide range of altitudes from 350 to 7,000 meters above sea level. It is the second largest producer of apples in India, accounting for approx. 25% of the country's total apple production. In 2020/21, Himachal Pradesh produced ca. 600.000 metric tons (MT) of apples, with an area of approx. 100.000 hectares under apple cultivation. The Delicious variety of apples constitutes the majority of apple production in the state, accounting for around 70% of the total apple production, followed by Red Delicious and Golden Delicious varieties. Most of the apples produced in the state are sold in the domestic market. The state's apple industry provides direct and indirect employment to around 700.000 people, including farmers (300.000), laborers, and other stakeholders involved in the production, processing, and marketing of apples.

Various government policies and programs regulate the apple market in HP, but most of the programs in place are back-ended, meaning that farmers receive compensation only after they have made investments. This presents a major challenge for many farmers who lack access to upfront capital in the first place. Another major issue is the lack of regulation in the quality check process. Quality standards in the region are vague and voluntary, and not uniformly enforceable by law. Although there are organic certification schemes in place, the prices for organic apples are not significantly higher than non-organic apples. This discourages farmers from switching to organic farming. However, there is a significant price premium for high-quality, grade A apples in the Himachal Pradesh market, both at the consumer and retail level. This premium can reach up to INR 250-300 per kg and is determined by factors such as color, shape, appearance, visual appeal, and firmness. In contrast, B and C grade apples are often used for processing, such as juice or wine production. While around 70% of B and C grade produce goes for processing, the remaining 30% is often left idle after harvest. To address this, the Himachal Pradesh Marketing cooperation procures B and C grade apples to process them into jam, jelly, and other products, catering to both small-scale and organized players.

There is a high price volatility throughout the year. While apple prices tend to be low during harvest season in October, November, and December due to a sudden glut in supply, prices tend to rise during February to April. This low-to-peak price fluctuation can be as high as 40%, but premium and super-premium quality grade A apples rarely exceed the INR 200-300 per kg range at the consumer and retail level.

One major issue for small-scale farmers in Himachal Pradesh is, that the existing large-scale farmers and private cold storage operators, who also rent out their extra space, set the market prices as they provide the majority of the stored apples and can therefore decide when they open the cold stores. The small farmers are thus forced to sell at the same period under worse conditions. Another problem is that payments made to farmers in Himachal Pradesh are based on the amount of crates rather than the weight of the apples procured. Farmers receive crates ranging from 18 to 25 kilograms with no difference in the procurement price. This often leads to exploitation by intermediaries during the harvest season when farmers are desperate to sell their produce.

PHL in the Himachal Pradesh apple VC ranges from 6% to 20%, depending on variety and stage of handling. An optimistic assumption of only 7% PHL in the Himachal Pradesh apple VC, would result in an estimated US$40 million loss in value.

5.2 Post-Harvest Losses

Step in VC	Activities	Inputs	Stakeholders	Potential Reasons PHL
Pre-production	Selecting and preparing land for planting	Land, soil testing, water, seeds	Farmers, government agencies, soil testing labs	Poor soil quality, inadequate irrigation, disease outbreaks
Production	Planting, Irrigation and Fertilization, Pest-and Disease management, Pruning, Thinning	Land, water and irrigation system, fertilizers, pesticides, equipment, labor	Farmers, Government agencies, input suppliers	Pest and disease infestations
Harvesting	Picking the apples from the trees	Labor, picking tools (ladder, buckets, bags, carts, bins, etc.)	Farmers, laborers	Bruising or damage during harvesting, inadequate storage conditions
Sorting and Grading	Sorting and grading apples based on quality and size	Sorting equipment, grading criteria, labor	Processors, wholesalers, grading agencies	Inconsistent grading standards, human error, poor sorting equipment
Packaging	Packaging the sorted and graded apples for transport and sale	Packaging materials, labels, labor	Wholesalers, packaging companies	Inadequate packaging materials
Transport	Transporting the packaged apples from the farm to a storage or processing facility, and then to the market	Trucks, refrigeration systems, fuel	Logisticians, transport companies	Poor transportation conditions (i.e. temperature), delays, poor handling, theft or damage
Storage	Storing the apples in a cool, dry environment to maintain their quality and freshness	Cold storage units, refrigeration systems, labor	Storage facilities, Solar panel providers, Electrical engineers, Maintenance & Repair services	Inadequate or non-existing temperature or humidity control, pest infestations, equipment failure
Processing	Processing the apples into a variety of products, such as juice, cider, or apple sauce	Processing equipment, labor, additives	Processing facilities	Quality issues with raw materials, equipment failure, incorrect processing methods
Marketing	Promoting and selling the apples and their products to consumers	Advertising and marketing materials, sales channels	Marketing agencies, retailers, distributors	Poor marketing strategies, inaccurate labeling, spoilage during storage or display

5.3 Innovation

Brief Description
The focus of the introduced measure is to combat PHL in the apple VC during storage by introducing climate-intelligent cold storages at smallholder level. The use of solar-powered technology plays a central role. Farmers, government officials and financial stakeholders are sensitized to the issue of PHL mitigation using renewable technology-based solutions. Most farmers in Himachal Pradesh do not have access to near-farm infrastructure and must rely on private or large corporate-owned controlled atmosphere (CA) stores/cold stores to store their produce. This intervention facilitates affordable access to energy-efficient post-harvest technologies and management practices. Key energy services such as cooling, precooling, sorting, and grading are solarized to reduce the carbon footprint of key operations and long-term lifecycle operational costs.[2] Two variants of cold storages are deployed: - A 10 MT variant with a capacity to store up to 500-600 crates of apples, with each crate holding approximately 20 kg of apples - A 20 MT variant with a capacity to store up to 1.000-1.200 crates of apples, with each crate holding approximately 20 kg of apples

Target	Target Group
- Aims at improving the marketable quality of the product (thereby increasing price per unit) - Aims at decreasing spoilage/waste (thereby increasing volume of marketable product) - Facilitating the integration of farmers into wider, remunerative markets to create and enhance value within the farmer community	Smallholder apple farmers (producing <2.500 boxes/year), organized into interest groups, collectives, grower societies, farmer-producer companies, or cooperatives

Geographical Location	Timeframe
Himachal Pradesh, mostly in the apple growing districts of Shimla, Kullu, Chamba and Mandi	2021 to 2024. At the time of the study five cold storage have been installed and another 14 were currently under construction.

Ownership
The "Cooling as a Service" (CaaS) model provides access to cooling technologies as a service for smallholder farmers, who may not have the resources to invest in such technologies themselves. A third-party service provider owns and operates the cooling infrastructure and charges a fee for its use, either on a pay-per-use or subscription basis. This approach can reduce the upfront costs for farmers and provide them with access to energy-efficient cooling technologies that can help to reduce PHL and increase the value of their produce.

[2] Most of the cold storage sites have pre-existing sorting and grading facilities, independently installed by the farmers themselves. However in some cases, both cold store and sorting grading facilities are installed in an integrated pack house concept.

Framework conditions

To ensure that the location of the cold storage facility is optimized for the needs of the small-scale producers, both the geographic and market environment criteria should be considered.

Geographic	Market
Location Specific Analysis	Production and Crop Mix
Suitable altitude, analyzed for its solar potential to ensure sufficient sunlight to power the facility. Analysis of soil type, topography, and water availability, to ensure the location is suitable for construction	An assessment of crop mix and crop calendar should be conducted to analyze crop-wise production by cluster and determine the types of products that will require cold storage
Market Proximity	Marketable Surplus
Should be in proximity to major markets to reduce transportation costs and ensure timely delivery of products to customers.	The estimation of marketable surplus after considering self-consumption and direct sales through traditional channels is crucial for determining demand
Last-mile Infrastructure	Ability to Pay
Access to road networks and power grids, as well as the quality of power supply should be considered to ensure consistent power supply and an easy movement of products to and from the storage facility.	Income levels of smallholder cooperatives should be analyzed to assess their ability to pay for cold storage facilities. This should also consider their ability to wait for better prices in the market.

The cold storage has the potential to provide a reliable market for the producers as it allows them to sell their produce off-season at a higher price, while reducing the risk of spoilage and waste. As the cold stores are relatively small with 10-20MT MT capacity, a single farmer could theoretically fill the cold store with her crop. However, the reality is that due to the high up-front costs of inputs and equipment, farmers in Himachal Pradesh are forced to sell about 70% of their produce immediately after harvest and can only store about 30%, which equates to about 300-400 crates. Therefore, groups of 3-10 farmers have to join together to utilize the cold storage facilities at full capacity. The idea is that accountability contracts are undertaken between the storage provider and Farmer Producer Companies/ Cooperatives who themselves decide which of their member farmer interest groups will receive a storage facility. A direct channel with farmer groups and/ or cooperatives is established via the CaaS model. The scheme overcomes the main issue of ability to pay, as small-scale farmers have limited financial resources.

The major geographical challenge is that due to poor accessibility and road infrastructure in HP, the storage providers are exposed to high operational costs. The management and maintenance of cold storage facilities is currently seen as the biggest hurdle to the economic sustainability. To counteract these hurdles, the long-term concept therefore envisages to cluster the cold storage facilities geographically. This however means, that the innovation will only be economically viable after it has been scaled up and widely disseminated, requiring large upfront capital risks or need of subsidies beforehand.[3]

Competition for the on-farm solar cold storage comes from other large-scale cold storage facilities located in the same region. Advancements in transportation and preservation technology could pose a potential future threat to the local cold storage, as they may provide alternative options for storing and transporting apples.

Access to essential suppliers and services is also important for the economic success of the cold storage. Currently, key supplies must be transported from large distances and local service providers require training.

Service	Need	Local Conditions
Solar panel suppliers	To set up a solar-powered cold storage system, solar panels are required to generate electricity. Thus, suppliers of high-quality solar panels are involved in the implementation process	Bangalore, Karnataka (extremely large distance: approx. 2.500km)
Electrical engineers	The cold storage system will require specialized electrical wiring and systems, which will need to be designed and installed by experienced electrical engineers	Local resources are trained and used for electrical engineering.
Cold storage manufacturers	Suppliers of cold storage units are required to provide high-quality units that can maintain the desired temperature range for storing apples	Vadodara, Gujarat (large distance: approx. 1.300 km)
Installation services	A team of experienced technicians is required to install the solar panels, cold storage units, and electrical wiring and systems	Local resources are trained and used as service installers
Maintenance and repair services	Regular maintenance and repair services will be required to ensure that the cold storage system continues to function effectively over the long term	Vadodara, Gujarat (large distance: approx. 1.300 km)
Transportation services	The transportation of apples from farms to the cold storage facility and then to market requires efficient and reliable transportation services	Local transportation service providers are used
Financing institutions	The implementation of a solar-powered cold storage system is a significant financial investment. Therefore, financing institutions must be involved in the process to provide the necessary funding	State Cooperative Bank and nationalized commercial banks

3 Unfortunately, a detailed breakdown of the operational costs was not available at the time of the study and should therefore be prepared immediately for funding purposes.

Business Model Canvas

Key Partners
-Electrical engineers
-Cold storage manufacturers
-Installation services
-Maintenance and repair services
-Transportation services
-Finance institutions
-Solar panel suppliers

Key Activities
-Customer service including transportation, payment options, technical support
-Establish efficient and reliable distribution channels to transport apples from farms to the cold storage facility, and from the facility to the market
-Develop flexible payment options and financing models to cater to the needs of small-scale producers
-*Explore new revenue streams by offering value-added services such as sorting, grading, and packaging of apples*

Key Resources
-Physical infrastructure
-Technology and equipment
-Skilled workforce
-Transportation and Logistics
-Financial resources
-Partnerships and collaborations

Value Propositions
-Strategic location near major apple producing areas minimizes transportation costs
-Allows to sell at a later point in time, securing higher prices on the market
-Reduces PHL and extends shelf life of apples by creating optimal storage conditions, including temperature and humidity control
-Solarizing key energy services, reducing the carbon footprint of key operations

Customer Relationships
-Apple producers/farmer cooperatives: Access to cooling technologies for smallholder farmers via CaaS
-*Downstream - Processors and Marketers: Transactional selling the apples at an agreed-upon price (fixed contracts)*

Channels
CaaS for farmer cooperatives involves a third-party service provider who owns and operates the cooling infrastructure and charges a fee for its use, either on a pay-per-use or subscription basis

Customer Segments
-Smallholder apple producers/Farmer cooperatives: Allows selling apples at a higher price (off-season), negotiate better prices and earn more income, while also reducing the risk of spoilage and waste
-Processors, Marketers, Buyers and Retailers: Consistent and high-quality supply of apples, reducing the risk of shortages and price spikes

Cost Structure
For Cooperatives
-Fee for quantity of apples stored
For Cold Storage Service Provider
-Capital costs for building and maintaining the cold storage facility
-Operating costs such as electricity, water, and labor costs
-Transportation costs for moving the apples to and from the cold storage
-The technical expertise and management required to operate
-Developing and maintaining relationships with smallholder farmers, buyers, and other stakeholders in the apple VC

Revenue Streams
For Cooperatives
-Preservation of the quality and shelf life of apples
-Reduction of PHL
-Enabling to sell their produce at a higher price at a later date when market conditions are favorable
For Cold Storage Service Provider
-Storage fees
-Transportation fees
-Fees for additional services such as sorting and grading

**italics: optional activities not yet part of business plan*

Economic Valuation

The cold storage intervention requires a combination of physical, technological, human, financial, and networking resources to effectively deliver value propositions, build relationships, and generate revenue streams. This includes the p*hysical infrastructure* (temperature-controlled storage rooms, solar panels, ventilation systems, and backup power supply); other *technology and equipment;* a *skilled workforce* for the proper handling, sorting, grading, and storing of apples; as well as t*ransportation and logistics*.

The cold storage is offered under a CaaS scheme which means that the farmers who store their products do not bear the costs, but the technical provider does. Revenue streams for the *cold storage provider* may include storage fees, transportation fees, and fees for additional services such as sorting and grading. The fee for using CaaS should be based on the total costs of installing, operating, maintaining, and financing the equipment. *Farmers* pay for the value that the cold storage provides in terms of preserving the quality and shelf life of their apples, reducing PHL, and enabling them to sell their produce at a higher price later when market conditions are favorable.

For the economic sustainability of the investment, both the profitability on the side of the farmer, and the profitability on the side of the cold storage provider must be considered. The profitability on the side of the farmer is achieved if the additional profit due to lower crop losses and higher prices exceeds the storage fee. The profitability on the side of the cold storage provider is achieved if the storage fee exceeds the capital and operation costs.

It was estimated that the intervention can increase marketable apple volumes by 25-30%, which otherwise would have been lost as PHL and value by 30% since quality is retained for longer duration. In a first test phase, Himachal Pradesh farmers who stored their produce for 4 months, received a price increase of 19 Rp per kg. Paying a CaaS fee of 1.6 Rp per kg and month this resulted in 12.5 Rp per kg higher revenue. The economic sustainability for the storage provider is however not ensured with the fee. Even with a 100% utilization of the storage, the 32 Tsd. Rp monthly fee income would not cover the interest costs (estimated at 14.5 Tsd. Rp. per month), monthly operational costs (estimated at ca. 17 Tsd. Rp per month) as well as the cost of depreciation (estimated at ca. 20 Tsd. Rp per month including a 50% subsidy). To ensure long-term economic sustainability, a nearly 100% capacity utilization at a doubled CaaS fee rate would need to be achieved, or other revenue streams such as transport or other service fees would need to be explored. The creation of a strategy and business plan is imperative.

Financing

The CaaS model addresses the constraint of limited financial resources faced by farmers by bypassing any initial investment requirements. Through this model, no financing is required as they are only paying for the amount of food they store (per kg/day) in the cold rooms, avoiding any upfront investment. However, on the technology provider's end, a significant amount of money is required to invest in equipment. Currently, the financing could only be ensured via the integrated development partnerships with the private sector (iDPP) model in cooperation with CoolCrop Technologies Private Limited. In the future, the technology will require bridge finance to meet the capital expenditure. Potential solutions are blended finance models, other banking solutions and the complementation with existing subsidy schemes.[4] One potential approach is a sale-leaseback model. In this approach, a bank or financial institution buys the equipment and then rents it back to the cooling system service provider (usually for a period that is no longer than the CaaS contract period). This transaction is called an asset-backed transaction, which means that an operating asset is leased to the technology provider for the duration of the contract. This approach is more secure for the finance provider. The contract between the technology provider and the customer (CaaS contract with farmers) is used as additional collateral, and a payment guarantee from an insurance company or an investment from a fund can exist to protect the equipment provider from customer payment default. At the end of the contract, the ownership of the equipment returns to the technology provider.

Conclusion and Recommendations

The cold storage intervention has significant potential for scaling up and replication, reducing not only PHL but also greenhouse gas emissions. However, it requires additional resources, stakeholder involvement, and a blended finance business model for sustainable and inclusive economic growth. Collaboration among various stakeholders is crucial, including farmer cooperatives, government agencies, financial institutions, and private sector partners. The major recommendations are:

1. *Business Model*: A CaaS model requires a viable and sustainable business model, which includes the pricing strategy, payment terms, and service level agreements with the smallholder farmers. The pricing strategy should be attractive enough to encourage farmers to use the facility, while also covering operational costs. This should be drawn up urgently and consider different scenarios of geographical utilization.
2. *Production and Crop Mix*: An assessment of crop mix and crop calendar should be conducted to analyze crop-wise production by cluster and determine which other products can be stored to ensure full capacity utilization and capitalization.
3. *Funding*: The initial funding required for setting up the cold storage facility is significant. A funding strategy should be developed and could come from a combination of sources, such as government subsidies, private investments, or microfinance institutions.
4. *Maintenance and Repair*: Regular maintenance and repair of the cold storage facility are critical to ensure its longevity and efficient operation. A maintenance plan should be developed and costs calculated for different scenarios of geographical coverage.
5. *Partnerships*: Partnerships with other organizations or stakeholders can help to reduce the costs of setting up and operating the facility. This could include partnerships with energy providers, logistics companies, and farmer cooperatives.
6. *Training and Capacity Building*: While the cooperative usage approach promotes collective ownership and decision-making it can lead to conflicts or disagreements among users. Consequently, there is a high need for capacity building as strong management and technical expertise are required. Outreach programs must be developed to ensure effective utilization and establish strong business models with forward market linkages.

[4] At the time of the study. GIC India is in discussion with a bank to leverage a federal government scheme that provides capital at almost 20-25% lower interest rates than the market rate (which is in 12% -14%/annum range). This fund has been specifically created to promote near farm agriculture value added infrastructure and comes with a Federal Government Credit Guarantee facility

6 Vietnam – Mango – De-Sapping/Hot-water Treatment – Business Case

The mango VC in the South of Vietnam is a significant contributor to the country's agriculture sector and has been growing exponentially in the past 25 years. In 2021, Vietnam exported approx. 180.000 metric MT of fresh mangoes worth USD 120 million, with China, the US, and Japan being the main export markets. In Vietnam around 87,000 hectares are used for mango production. In the South of Vietnam, the provinces of Dong Thap, Tien Giang, and Vinh Long are the major mango-growing regions, accounting for ca 50% of the country's total production. In these provinces, the Keo Cot variety is the most popular, representing around 60% of the total mango production, followed by the Cat Chu and Hoa Loc varieties.

Due to increasing export volumes efforts are made to promote the adoption of food safety and quality regulations in the mango VC in Vietnam. The Vietnamese Good Agricultural Practices (VIETGAP) and the One Commune One Product (OCOP) program are two initiatives that have been introduced to support small-scale farmers in this regard. VIETGAP is a set of standards and practices aimed at ensuring food safety and traceability throughout the entire agricultural VC, including the mango sector. OCOP, on the other hand, focuses on promoting the development of high-quality products from specific regions in Vietnam, including mangoes, and encourages farmers to adopt good agricultural practices and comply with food safety regulations. However, adoption rates of those standards remain low.

Prices for Mangoes fluctuate substantially throughout the year and can range between 15000 VND/kg and 48000 VND/kg at the farm gate. The main reasons for these substantial price differences are the oversupply during high season and the undersupply during low season (early and late harvest). Prices also vary across different varieties. Cat Chu mangoes are the most popular ones and are often sold at a higher price due to their sweet taste, soft texture, and attractive appearance. However, prices can vary significantly depending on the region and market. The premium price is about 30-40% higher for high quality grade A mangoes.

The GIC project is active since 2021 and supports 5 cooperatives in the region. Cooperatives usually only produce one specific variety. In the promoted cooperatives the produce is procured at the farm gate. The farmers transport their produce to the cooperative and generally receive a lump sum for the total produce provided which includes a mix of Grade A, B and C Mangoes. Sorting and grading takes place at the cooperative level only. PHL in the Mango VC in the GIC project regions are estimated at 5% at farm level, 7% at whole seller level and 25-30% at the retail level, depending on the variety and the stage of handling.

6.1 Post-Harvest Losses

Step in VC	Activities	Inputs	Stakeholders	Potential Reasons PHL
Pre-production	Land preparation, variety selection, nursery establishment, planting	Fertile soil, good quality seeds	Farmers, agro-dealers, input suppliers	Poor quality seeds, inadequate land preparation, pests and diseases
Production	Flowering, pollination, fruit setting, Irrigation, fertilization, pruning, and pest/disease control	Water, fertilizers, pesticides	Farmers, laborers	Lack of knowledge, poor quality inputs, pest and disease outbreaks
Harvesting	Picking the mature fruits	Labor, tools, storage containers	Farmers, harvesters	Overripe or under ripe fruits, improper handling and storage
Post-harvest Handling	Sorting, grading, washing, and packaging	Sorting and grading machines, water, packaging materials	Traders, processors	Poor handling, damaged fruits, inadequate storage and transportation
Storage	Cooling, controlled atmosphere storage, ripening, and cold chain management	Cold storage facilities, temperature control equipment, packaging materials	Cold storage operators, transporters, traders, retailers	Temperature and humidity fluctuations, pests and diseases, inadequate storage, poor handling
Processing	Sorting, washing, peeling, cutting, pulping, pasteurizing, and packaging for different products (juice, dried mango, etc.)	Processing machinery, water, packaging materials	Processors, laborers, traders, retailers	Inefficient processing techniques, use of substandard equipment, improper processing techniques
Transport	Loading, transportation, and unloading	Refrigerated vehicles, fuel, labor	Transporters, traders, retailers	Rough handling, inadequate ventilation, temperature fluctuations, long transport times and delays
Marketing	Transportation, storage, and sales	Transportation vehicles, storage facilities	Traders, wholesalers, retailers, consumers	Poor market access, low demand, inadequate market information, poor handling during transportation

6.2 Innovation

<table>
<tr><th colspan="2">Brief Description</th></tr>
<tr><td colspan="2">De-sapping, also known as de-gumming, is a process of removing the sap or gum from the surface of mango fruits. This is done by soaking the fruits in a solution of hot water and a mild detergent or a citric acid solution. The solution softens the sap, making it easier to remove. The fruits are then washed in clean water to remove any remaining solution and sap. This process not only improves the appearance of the fruits by making them look cleaner, but it also reduces the chances of post-harvest fungal and bacterial infections.
Hot water treatment involves subjecting the fruits to a high-temperature treatment to eliminate any insects or pests that may be present on the surface of the fruits. This is important for meeting phyto-sanitary standards and also helps to extend the shelf life of the fruits. This process does not only kill any pests or insects but also stimulates the natural ripening process of the fruits, resulting in a more consistent ripening and improved fruit quality.</td></tr>
<tr><th>Target</th><th>Target Group</th></tr>
<tr><td>- Reduce post-harvest losses due to anthracnose disease caused to mango.
- Improve the fruit quality for further transportation to domestic and export markets.
- Improve the shelf life of mango to at least 21 days after harvest to enable transportation to Hanoi and other urban domestic markets.</td><td>The facility will be implemented at Cooperative level. The project supports five cooperatives which are eligible for the intervention.</td></tr>
<tr><th>Geographical Location</th><th>Timeframe</th></tr>
<tr><td>6 provinces in Mekong delta: An Giang, Dong Thap, Can Tho, Kien Giang, Hau Giang and Soc Trang</td><td>January 2023 to June 2024. At the time of the study only the first test phase has been finalized.</td></tr>
<tr><th colspan="2">Ownership</th></tr>
<tr><td colspan="2">Cooperative level and company level</td></tr>
</table>

Framework conditions

To ensure the economic sustainability of de-sapping and hot water treatment interventions in the mango VC, the market environment as well as the regulatory policy and institutional environment must be favoring.

Market	Policy/ Institutions
Access to Markets	Quality Standards
The mango cooperatives must have access to local and domestic urban markets. This requires a well-functioning market system with clear price signals, reliable transportation, and efficient distribution channels.	Mangoes have to meet the required standards for consumer consumption which may include physical and chemical characteristics, packaging and labeling as well as phytosanitary requirements.
Market Demand	State Regulations
The market must have a demand for high-quality mangoes that meet quality standards. This requires understanding the specific preferences and requirements of the target markets, and producing mangoes that meet these requirements.	May include licensing requirements, inspection and certification procedures, and enforcement mechanisms. Compliance with state regulations is important for maintaining public health, protecting the environment, and ensuring consumer confidence in the mango VC.
Market Price	Institutional Support
The price premium received for the treated mangoes must be sufficient to cover the additional costs of de-sapping and hot-water treatment.	The mango VC requires institutional support from government agencies, industry associations, and other stakeholders to promote good agricultural practices, facilitate access to finance, and provide technical assistance.

In the present case, both conditions are largely fulfilled. Regulations and quality standards are in place. Even though they have only been implemented to a small extent, their relevance will increase in the coming years. The demand for high-quality mangoes is high, especially in urban conurbations such as Hanoi. The market environment is therefore generally favorable for the innovation. The long-term goal of the cooperatives is to market the high-quality Grade A mangoes to supermarkets in the greater Hanoi area. Marketing of mangoes from the Mekong Delta has been difficult so far, as quality requirements and the necessary shelf life for the long transport route is not yet guaranteed. The intended preservation of 21 days will allow enough time for transport and distribution of the fruits through wholesale markets and retail stores in domestic urban areas.[5] On the other hand, large-scale commercial farms emerge as a significant source of competition due to their access to abundant resources and economies of scale. This enables them to produce and market mangoes at competitive prices. Moreover, their established relationships with urban retailers and distributors enhance their market presence. To counter the competition effectively, the supported cooperatives must focus on implementing effective marketing strategies, and forging partnerships with retailers.

[5] However, the expected preservation will not allow marketing beyond the domestic market since the foreseen 21 days durability are not sufficient for the Mangoes to stand the long duration of sea freight.

Business Model Canvas

<table>
<tr><th>Key Partners</th><th>Key Activities</th><th>Value Propositions</th><th>Customer Relationships</th><th>Customer Segments</th></tr>
<tr>
<td rowspan="3">-Mango Farmers: Collaborating with mango farmers to provide access to their mangoes for treatment
-Equipment Suppliers: Partnering with suppliers of de-sapping and hot water treatment equipment
-Chemical Suppliers: Collaborating with suppliers of cleaning and disinfectant chemicals
-Technical Consultants: Engaging technical consultants to provide expertise and guidance</td>
<td>-Facility setup and maintenance
-Carrying out the treatment processes
-Conducting quality control inspections to ensure compliance with standards
-Providing training and support to farmers and operators
-Establish efficient and reliable distribution channel to transport mangoes from farms to the facility, and from the facility to the market
-Establish effective market channels</td>
<td rowspan="3">-Phytosanitary Compliance: Ensuring that mangoes meet international phytosanitary standards
-Enhanced Market Access: Enabling mango farmers to access domestic and international markets
-Improved Quality: Enhancing the quality and shelf life of mangoes through treatment</td>
<td>-Personalized Service: Providing personalized assistance and support to mango farmers during the buying process at the farm gate, including guidance on harvesting practices and quality standards.
-Account Management: Establishing and maintaining strong relationships with supermarkets, ensuring timely delivery of treated mangoes and addressing any concerns or requirements they may have.</td>
<td rowspan="3">-Mango Farmers: Smallholder farmers engaged in mango cultivation, providing a reliable source of mango supply for the treatment process
-Supermarkets: Domestic urban supermarkets that aim to offer high-quality, treated mangoes to their customers, meeting their demand for safe and premium produce</td>
</tr>
<tr><th>Key Resources</th><th>Channels</th></tr>
<tr>
<td>-Mango Farmers: Smallholder farmers engaged in mango cultivation, providing a reliable source of mango supply for the treatment process
-Supermarkets: Domestic urban supermarkets that aim to offer high-quality, treated mangoes to their customers, meeting their demand for safe and premium produce
-Transportation and logistics
-Financial resources</td>
<td>-Farm Gate Purchases: Engaging directly with mango farmers at farm gate to buy the mangoes for treatment, fostering a direct and transparent relationship
-Supermarket Distribution: Collaborating with supermarket chains to supply mangoes directly to distribution centers, ensuring efficient and reliable delivery</td>
</tr>
<tr><th colspan="2">Cost Structure</th><th colspan="3">Revenue Streams</th></tr>
<tr>
<td colspan="2">-Equipment and Infrastructure Costs: Investment in de-sapping and hot water treatment facilities and equipment
-Chemical Costs: Procuring cleaning and disinfectant chemicals
-Operational Costs: Maintenance, utilities, and labor expenses
-Transportation costs: Moving the mangoes to and from the facility
-Technical expertise and management: Required to operate facility
-Relationships: Developing and maintaining relationships with smallholder farmers, buyers, and other stakeholders in the apple VC</td>
<td colspan="3">-Reduction of PHL
-Preservation of the quality and shelf life of Mangoes,
-Enabling to sell produce at a higher price to urban supermarkets</td>
</tr>
</table>

**italics: optional activities not yet part of business plan*

Economic Valuation

A successful implementation of the de-sapping and hot water treatment intervention requires the integration of various resources. These resources encompass physical, technological, human, financial, and network aspects. The innovation requires facilities such as treatment tanks, water heating systems, infrastructure to maintain optimal conditions, including solar panels for energy efficiency and backup power supply to ensure uninterrupted operations. Trained operators are required who can handle the equipment, follow proper procedures, and ensure the quality and safety of the treated mangoes. A reliable transportation and logistics system is essential to efficiently transport mangoes from the farm gate to the treatment facility, and then to the urban domestic market. This requires coordination, timely delivery, and proper handling to maintain the freshness and quality of the treated mangoes. Collaborating with supermarkets will allow the cooperative to establish a strong distribution channel, access the urban domestic market, and meet quality and quantity requirements. Partnerships with member farmers ensure a steady supply of high-quality mangoes, creating a consistent and traceable supply chain for the treatment process. However, setting up the collaboration and partnerships does require that upfront investments are made.

The revenue stream of the intervention is influenced by its impact on reducing PHL. Through the effective treatment of mangoes, this intervention aims to minimize spoilage and extend the shelf life of the fruit, resulting in an increased marketable yield and new market channels. This reduction in PHL has the potential to enhance the cooperative's revenue stream by enabling higher sales volumes and improved profitability. Furthermore, the intervention's ability to deliver higher quality mangoes may allow for premium pricing, further contributing to the overall economic sustainability of the intervention.

According to a simulation by the CP which is based on the assumption that PHL can be reduced by 15% the additional turnover for the high value Cat Hoa variety for a cooperative producing 2.200 MT per year, could amount to around 15 billion VND (570.000 EUR) per year. The total investment cost of around 10.000 € is only around 1,7% of the additional income which can be generated in one year (IRR 14490%). However, these calculations are highly dependent on the optimistic assumption regarding the potential level of PHL reduction and utilization of available processing capacity and the specific high value variety. For the less valuable varieties the investment would not be economically viable. Even for the high value varieties a PHL reduction of only 5% and a resulting low market price for the sold fruit can render the investment unprofitable.

The issue of capacity utilization poses the major challenge, as the mango season peaks and the harvest is not evenly distributed over the year. During periods of high mango supply, the innovation's treatment facility may operate at full capacity, which potentially makes it challenging to process all the harvested mangoes. This could result in some mangoes being left untreated and susceptible to PHL. Inefficiencies may arise if the facility is unable to effectively handle the fluctuating volumes of mangoes during different stages of the season, potentially impacting the overall effectiveness of the intervention. The current business model does not take these constraints into account. Managing the capacity utilization issue will require strategic planning, resource allocation, and potentially considering alternative solutions to accommodate the surge in mango supply during peak harvest periods.

Financing

Implementing the innovation involves significant financial investments. This includes capital expenditures for setting up the treatment facility, purchasing equipment, and acquiring necessary resources. Ongoing operating costs such as electricity, maintenance, and staff salaries also need to be considered. The investment costs for the de-sapping and hot water treatment machines are estimated at 255 Mio VND (10.000 €) with a capacity of roughly 3 MT/ Day. It is anticipated 30% of the total investment should be covered by own capital of the cooperatives and the rest covered by a bank loan with an anticipated interest rate of 15%. With a five year repayment period the interest costs on the loan will increase the total investment costs by 30%. However, it should be noted that the cooperatives' lack of assets for mortgage may result in a higher interest rate, potentially impacting the profitability of the investment. A detailed financing plan is yet to be developed at the time of the study.

6.3 Conclusion and Recommendations

In conclusion, investing in the de-sapping and hot water treatment innovation presents a promising opportunity to combat PHL and at the same time generate revenue for the cooperatives and their associated farmers. By addressing key challenges related to phytosanitary compliance, this innovation can improve the quality of mangoes and open up access to broader domestic and potentially even international markets. A successful implementation of the innovation will require collaboration and partnerships with key stakeholders, including mango farmers, equipment suppliers, retailers, and government agencies. To ensure economic sustainability, it is essential to understand the market dynamics, consumer preferences, and demand for treated mangoes. This will enable targeted marketing efforts, efficient production planning, and competitive pricing strategies to capture a significant share in the domestic urban market.

The major recommendations are:

1. *Capacity Utilization Optimization*: Proactive planning and forecasting should be implemented to anticipate peak mango seasons and adjust the capacity of the treatment facility accordingly, ensuring optimal utilization during periods of high mango supply.
2. *Financing*: The initial funding required for setting up the de-sapping and hot water treatment facilities are substantial. A financing strategy should urgently be developed considering the capacity of cooperatives to provide own capital for the investment and resulting interest loans from the banks.
3. *Market Research and Demand Analysis*: Conduct thorough market research to identify consumer preferences, market trends, and demand for treated mangoes. This will help align production and marketing strategies with market needs, ensuring a steady customer base and sales.
4. *Supply Chain Collaboration*: Foster collaborations and partnerships with other actors in the mango VC, such as packers, processors, or exporters. This will streamline the supply chain, optimize distribution, and potentially lead to cost savings and expanded market reach.
5. *Farmer Capacity Building*: Invest in farmer capacity building initiatives to enhance their knowledge and skills related to best agricultural practices, post-harvest handling, and quality control (including on farm sorting and grading). This will improve the overall quality of the mangoes supplied, increase farmer productivity, and strengthen their engagement in the innovation.

7 Mali – Rice – GEM Parboiler – Business Case

7.1 Context

The intervention is implemented in the Segou and Koulikoro regions which are one of the major rice producing regions in Mali. They are located a tropical climate zone characterized by hot temperatures and a pronounced rainy season. In 2020, the total rice production in Koulikoro and Segou was approx. 860.000 MT. Rice is an important food crop in the regions of Koulikoro and Segou and grown both for local consumption and for sale in regional and international markets. It is estimated that the rice sector employs approx. 3 million people in Mali.

There are quality standards for rice in Mali, covering various parameters such as appearance, texture, and moisture content and grain size. However, enforcement tends to be a challenge due to a lack of resources and capacity, thus some farmers and traders try to sell lower quality rice as higher grade to obtain a higher price. A significant amount of rice grown in Segou and Koulikoro is directly being processed in the regions. However, many rice processors operate on a small scale, using manual or semi-manual equipment, thus only processing a few bags of rice per day.

Rice prices in Mali can fluctuate throughout the year, depending on a variety of factors such as seasonal supply and demand, weather conditions, transportation costs, and market conditions. In general, rice prices tend to be highest during the lean season when rice stocks are low and demand is high. This typically occurs from June to September. During this time, rice prices may increase by as much as 30-50% due to the limited supply. During the harvest season, which occurs from October to January, rice prices may decrease as new crops become available and supply increases. However, prices can still fluctuate during this period depending on the quantity and quality of the harvest, transportation costs and market conditions.

A major challenge for rice farmers in Mali is the weak market infrastructure, including poor storage facilities and limited market access, which can lead to PHL, makes it difficult for farmers to access markets, and sell their produce at a fair price. At the same time, availability of credit for rice farmers is limited making it difficult for them to invest in improved measures. Many of the credit institutions have strict requirements for loan eligibility that can be difficult for small-scale farmers to meet. Interest rates on agricultural loans in Mali can be high, which makes it difficult for farmers to afford to take out loans. PHL in the rice VC in Mali is at approx. 10% of the production potential, resulting in a loss of earnings of 72 billion FCFA francs. Losses occur mostly during threshing, drying, and storage and to a more limited extend during transport.

7.2 Post-Harvest Losses

Step in VC	Activities	Inputs	Stakeholders	Potential Reasons PHL
Pre-production	Supply of inputs Land/soil preparation	Land, seeds, fertilizer, equipment, labor	Farmers, laborers, service/ input providers	Poor soil quality, inadequate irrigation, disease outbreaks, poor seed quality
Production	Sowing, transplanting, weeding, irrigation and fertilization, pest-and disease management,	Land, irrigation system, fertilizers, pesticides, equipment, labor	Farmers, service/ input providers	Pest and disease infestations, adverse weather conditions

Step in VC	Activities	Inputs	Stakeholders	Potential Reasons PHL
Harvesting	Extraction from the field and piling	Sickles, labor,	Farmers, laborers	Shattering (rice falls of stalks before or during harvest)
Sorting and Grading	Sorting the rice grains according to size shape and quality	Sieve shaker, color sorter, labor	Farmers, laborers	Mechanical damage such as broken grains
Threshing	Separating the rice grains from the straw, husk and other plant material	Thresher or flail, batton, labor, energy	Farmers, laborers, Cooperatives	Grain shattering due to improper handling, brittle varieties
Winnowing	Separating the grains from the chaff, straw and other impurities by tossing	Winnowing basket, tarp, fan, sieve, container	Farmers, laborers, women (cooperatives)	Grain loss due to too much air flow, remaining impurities if not done thoroughly
Cleaning	Removing any remaining plant material, stones and other debris from the grains	Sieves, air blowers, labor, water	Farmers, Cooperatives	Some grains are lost when washing out the chaff, dust or impurities
Parboiling	Rice grains are partially cooked by boiling them in water. The parboiled rice is then drained and cooled	Clean water, pots, stove/heat source, drains/sieves, fuel wood	Processors, cooperatives, laborers	Nutrient loss, grain breakage, water loss, starch loss
Packaging	Packaging in bags or containers for transport and sale	Bags containers, labor	Processors, Wholesalers	Inadequate packaging materials, poor handling
Milling	Removing the outer layers (bran and germ) from the rice grains to produce polished or white rice	Rice huller, whitener, energy	Cooperatives, Processors	Improper adjustment of mill leads to grain damage, bran may remain on rice of not done properly, impurities, loss due to low quality varieties
Drying	Reducing the moisture content of the rice grains to a safe level for storage (typically around 14%)	Solar dryer, mechanical equipment, tarps	Farmers, cooperatives	if not done long enough moisture content remains high and rice can catch diseases/ pest, impurities from improper handling
Transport	Transporting the packaged rice from the farm to storage or processing facility, market	Trucks, refrigeration systems, fuel, labor	Logisticians, transport companies	Poor transportation conditions (packaging, vehicles, roads) or handling

Step in VC	Activities	Inputs	Stakeholders	Potential Reasons PHL
				which leading to damage of grains
Storage	Storing the rice in a cool dry and well-ventilated place to prevent spillage	Warehouse, silo, pest control measures	Storage facilities, Maintenance & repair services	Poor infrastructure, pests and diseases, too high moisture content
Marketing	Promoting and selling the apples and their products to consumers	Advertising and marketing materials, sales channels, labor	Marketing agencies, retailers, distributors	Poor marketing strategies, inaccurate labeling, spoilage during storage or display

7.3 Innovation

<table>
<tr><th colspan="2">Brief Description</th></tr>
<tr><td colspan="2">Rice parboiling is a traditional method of preparing rice that enhances its nutritional value and taste. The process involves soaking the raw rice in hot water or steam, followed by partial boiling and drying. This technique not only improves the rice's texture but also increases its resistance to pests and diseases, making it suitable for storage in tropical climates. The innovation introduces an energy efficient rice parboiling method called GEM (Grain Quality Enhancement Machine). The heating of the GEM stove is powered by the use of rice husks which are a waste product of the hulling process, by which the rice is separated from its protective outer layer. Compared to other parboiling methods, GEM is more efficient, improves rice quality and uniformity and is less labor intensive. Using the husks as fuel reduces the use of fire wood and thereby combats deforestation.</td></tr>
<tr><th>Target</th><th>Target Group</th></tr>
<tr><td>-To improve the quality of parboiled rice (thereby increasing the unit price and thus the income of rice processing cooperatives).
-Reduction of PHL (thus increasing the volume of marketable product).
-Improved environmental sustainability and reduced health risks associated with the process.</td><td>The target group are women cooperatives who engage in rice processing. The women run groups mostly buy paddy rice and process it and are involved in rice production only to a limited extend.</td></tr>
<tr><th>Geographical Location</th><th>Timeframe</th></tr>
<tr><td>Three sites in three regions: Koulikoro Region: Baguineda, Segou Region: san y Dioro</td><td>October 2021- September 2023. During the time of the study the intervention was in a test phase.</td></tr>
<tr><th colspan="2">Ownership</th></tr>
<tr><td colspan="2">Ownership is at the cooperative level who are operating the GEM.</td></tr>
</table>

Framework conditions

The critical framework conditions identified in relation to the establishment of a parboiling operation are financial and market related.

Market	Finance
Market Demand and Consumer Preferences:	Capital Needs
Assessing the market demand for parboiled rice in Mali is crucial. Understanding consumer preferences, including taste preferences and preferences for parboiled rice over other rice varieties, will help determine the potential market size and target customer segments.	The GEM is usually integrated in a processing site with a paddy soaking tank, a rice husker, hoisting devices and cemented floors as improved drying surfaces. A storage facility is needed to store the rice procured during harvest season to assure year round operation of the parboiling operation. In addition, the paddy-rice is ideally bought in bulk at low prices during the harvest season, to last for the whole year.
Competitive Landscape	Access to Capital
Existing rice parboiling businesses and their market share, as well as the supply of imported parboiled rice, pricing strategies, and product differentiation need to be identified.	Sufficient access to capital is crucial and includes obtaining start-up funds for infrastructure, equipment, working capital, and operational expenses. Potential sources are banks, microfinance institutions, government programs, or private investors.
Distribution Channels	Favorable Financing Options
Identify existing distribution channels for rice products in Mali, such as wholesalers, retailers, local markets, restaurants and hotels or export opportunities. Opportunities to leverage existing channels or develop new ones should be evaluated.	It is essential to have access to appropriate financing options tailored to the needs of the women cooperatives. This may include loans with reasonable interest rates, flexible repayment terms, and grace periods that align with the production and sales cycles of the business. Support in setting up a revolving fund to purchase paddy rice on a regular basis is an example of such.

The market conditions for parboiled rice in Mali are favoring as consumer demand for far exceeds the volume of supply from domestic production, resulting in high imports. Parboiled rice is gaining popularity in urban centers. While the increase in consumption is undeniable, it is mainly met with imports from South-East Asian countries, rather than locally produced parboiled rice. Access to finance is the major hurdle. Substantial capital is required to set up a processing facility and to cover the operational costs related to purchasing sufficient raw material. Adapted financial products for this specific kind of business model do currently not exists.

Rice parboilers using the GEM technique face competition from other stove based parboilers such as the KIT 180 which used to be promoted by the GIC as well as traditional parboilers, offering their rice for lower prices (due to less requirements in terms of specialized knowledge and investment costs for equipment).

The parboiling unit should be located in a rice producing zone or close to a market where paddy rice is traded and sold in bulk. This reduces transportation costs, minimizes potential damage to the grains during transportation and further gives the cooperatives the opportunity to select high quality paddy for processing. Parboiling also requires a significant amount of water for soaking and steaming processes. Therefore, the unit should be located in an area with a reliable and clean water supply. The following service providers and suppliers are of importance when setting up a parboiling business:

Service	Need	Local Conditions
GEM manufac-turers	Local manufacturers for GEM equipment and accessories are required.	Local production is possible and has been pi-loted by the project. The costs are still high compared to the ones promoted by Afri-caRice, but should go down via up-scaling.
Maintenance and repair ser-vices	Regular maintenance and repair services will be required to en-sure that the GEM system con-tinues to function effectively over the long term	Introductory trainings may be necessary but sufficiently skilled service providers can be identified locally.
Financing insti-tutions	The implementation of a GEM powered parboiling operation is a significant financial invest-ment. Thus, financing institu-tions will need to be involved in the process to provide the nec-essary funding.	Financial options exists from the GIZ Agro-fi-nance project, but on the free market no adapted accessible products form processors exist.
Rice producers	The processors need a steady supply of high quality paddy at reasonable prices.	In order to assure a year round supply the processors should buy enough paddy during harvest time as this is when prices are most affordable. Buying at regular intervals throughout the year would result in high prices as the paddy is then sold by traders and wholesalers who buy and store the rice themselves.

Business Model Canvas

<table>
<tr><th>Key Partners</th><th>Key Activities</th><th>Value Propositions</th><th>Customer relationships</th><th>Customer Segments</th></tr>
<tr>
<td rowspan="3">- Paddy producers
- Local manufacturers of GEM equipment (hullers, sorters, mills)
- Suppliers of imported equipment (motors, roller hullers, engelberg hullers)
- Microfinance institutions and banks</td>
<td>- Processing of rice
- Establishment of relationships with paddy producers traders and wholesalers to acquire raw materials
- Development of distribution channels to transport the rice to- and from the processing plant
- Selling processed rice to consumers, traders, wholesalers or exporters</td>
<td rowspan="3">- Higher quality (higher nutritional value and taste) and quantity of parboiled rice
- Increases competitiveness and productivity
- Reduces PHL
- Increases income for women parboilers
- Using solar energy reduces deforestation the area and dependence on gas and contributes to climate change mitigation</td>
<td>- In person sales of parboiled rice directly to the customers (wholesalers, traders, restaurants)
- Sales at local markets (one-to-many)</td>
<td rowspan="3">- Local markets
- Restaurants / Hotels / Canteens
- Wholesalers, traders
- International market</td>
</tr>
<tr><th>Key Resources</th><th>Channels</th></tr>
<tr>
<td>- Raw material (good quality paddy)
- GEM equipment
- Skilled supervisory staff
- Financial resources
- Processing site with infrastructure (water supply, storage, drying)</td>
<td>- Networking, social advertising, community building</td>
</tr>
<tr><th colspan="2">Cost Structure</th><th colspan="3">Revenue Streams</th></tr>
<tr>
<td colspan="2">- Capital costs for GEM equipment
- Insurance
- Operating costs for electricity, water, rental costs for parboiling unit, labor costs
- Recurrent capital loan to buy raw material or to pre-finance the production of producers (contract farming)</td>
<td colspan="3">- Increase of sales price due to higher quality, better taste and conformity
- Increased sales due to higher output from parboiling process (less PHL)</td>
</tr>
</table>

Economic Valuation

The economic sustainability of GEM parboiling for women cooperatives depends on the ability deliver a high quality product which achieves sales prices, which cover the running costs and costs for acquiring and maintaining the GEM equipment. A successful parboiling facility requires physical infrastructure (processing site, drying and cleaning area, storage, access to electricity and water), technology and equipment (parboiling equipment, sorter, huller), a skilled workforce (management, accounting, advisory support), reliable transportation and logistics, and significant financial resources for capital expenditures and ongoing costs. The GEM requires less fire wood and labor by the women which results in reduced operation costs compared to other stoves. Given a consistent supply of high-quality paddy, the assumption is therefore that the high investments costs can be recovered in a short time.

AfricaRice which promoted the GEM in the region has analyzed the performance of the GEM and compared it to traditional parboiling, published the following results on their website[6]:

- Women make an extra 200 USD on every ton of rice parboiled compared to the traditional system
- Higher output rate of up to 25 MT of high-quality milled rice per month
- Reduced expenditure on firewood from 1.83 to 0.64 USD per 100 kg of paddy parboiled
- Reduced steaming time from about 60-90 min to 20-25 min per 50-100kg of paddy
- The IRR of the GEM is 70% compared to 14% for the traditional technology

Based on a study from December 2018 by the GIZ AgroFinance project, which compared the traditional parboiling method with the advanced KIT 180 stove, a hypothetical scenario in which the GEM performed according to the above AfricaRice parameters results in[7]:

Processing of 10 t of paddy	Traditional method	Kit 180	GEM @125 FCFA/kg	GEM @200 FCFA/kg
Gross margin (FCFA)	565.000	1.480.000	2.858.000	2.110.000
Net revenue (FCFA)	270.000	356.000	1.226.000	883.000
Break-even point (t)	2,9	1,3	3,3	6,1

The following results can be derived from this theoretical case:

- The GEM is more efficient and results in approx. twice as high gross margin compared to the KIT 180. This is the case when calculating with the following assumptions:
    - Reduction of required fire wood (around 1/3 reduction)
    - Reduction of required labor (around 1/3 reduction)
    - Improvement in rice quality (higher sales price 20%)
    - Increase in output due to less broken grains (16%)
- Despite much higher investment costs for the equipment (assumption in this scenario is that the GEM costs 10 times more than the KIT 180), it still achieves a higher net revenue (approx. 500.000 FCFA).
- The break-even point is at around 5 MT which can be achieved easily within one season.

6 http://www.ricehub.org/RT/post-harvest/gem-parboiling/

7 Full calculation available in the annex to this report or in excel format upon request.

- Locally parboiled rice in Mali has a bad reputation due to the bad taste people attribute to the rice processed by the traditional method. It is therefore not a given, that premium prices can be charged. Even if the local demand is high, there is a risk that this will be covered by imported parboiled rice which is considered to be superior in taste.
- Since the GIZ AgriFinance study in 2018, prices for paddy have risen to around 200 FCFA/kg – this would reduce the net revenue to levels below that of the KIT 180 – therefore the investment for the upgrade would not make sense from an economic standpoint.

Financing

For women cooperatives engaged in rice parboiling the main question when adopting the new GEM technology is the financing. The GEM technology is currently still much more expensive compared to other improved cooking stoves in Mali.[8] Well running established cooperatives who already have a processing site with critical infrastructure at their disposal (storage facility, drying spaces, husker, sorter) and have a modern set up for improved stoves, may be able to make the transition to the GEM, as their creditworthiness will be sufficient (own capital plus proven experience in running the operation). If this is not the case, the credit demand is likely to exceed what banks are willing to loan to a cooperative. Especially when considering the need to finance the procurement of substantial amounts of paddy rice. Currently the three pilot sites who have received the GEM are financed via the GIC. The project is currently looking in to setting up a revolving fund for the acquisition of the paddy via the AgFin[9] project.

7.4 Conclusion and Recommendations

In conclusion, investing in the GEM to reduce PHL can have significant economic and societal benefits, including reduced greenhouse gases. If the promising results of the AfricaRice study can be replicated and the national market conditions are favorable, the GEM parboiling kit offers significant potential for scaling up and replication. The GEM technology promises higher returns than the previously promoted KIT 180 and other traditional parboiling methods. However, the underlying assumptions should be verified by closely monitoring running operation to verify the underlying assumptions regarding the efficiency (increased output quality and quantity), the price development of paddy and the customer's willingness to pay for the higher GEM quality. Further, one needs to consider the labor capacity of the cooperatives to assure the overall management of a processing site. Logistics in acquiring, transporting and storing large amounts of paddy need to go hand in hand with bookkeeping and other managerial as wells as administrative tasks. With such a complex set-up, it begs the question whether the cooperatives can compete with commercial agribusiness players or importers of parboiled rice from abroad in the long run. The major recommendations are:

1. *Technical Feasibility*: An in-depth technical analysis of the GEM performance with monitoring data from the field has to be carried out to assess the potential improved efficiency. Does it require less input and result in higher quality and quantity of output compared to other improved stoves?
2. *Market Supply of Paddy Rice:* The supply of quality paddy has to be investigated. Why has the price for paddy risen in the past years while the prices for parboiled rice have

8 This is also the case if the price is brought down to the level of those GEM's produced abroad by AfriaRice, by up-scaling the local production.

9 Promotion of Agricultural Finance for Agri-based Enterprises in Rural Areas: The project implemented by GIZ advises and supports the expansion of financial institutions into the agricultural sector and assists them with developing adapted financial services in Mali.

remained more or less stagnant? Can one assure low prices by pre-financing producers to produce paddy at previously set prices and do cooperatives have the capacity to engage in contract farming? At what price does the business case become unsustainable?

3. *Market Demand*: The market demand for high quality parboiled rice should be evaluated before setting up further facilities. What price are local consumers willing to pay for locally parboiled rice and how does this compare to imported paddy? A marketing campaign to promote locally processed rice may help to get rid of the bad reputation and to improve the willingness to pay.
4. *Funding*: To scale up or set GEM processing units, initial and long-term funding is crucial. Funding could come from a combination of sources, such as government subsidies, private investments, banks or microfinance institutions. This will require a strong business case based on a thorough economic analysis.

8 Burkina Faso – Rice – Multifunctional Thresher – Case Study

8.1 Context

In Burkina Faso rice is the 4th popular cereal in terms of area and production and its demand, driven by population growth and urbanization, is constantly increasing. Rice production and commercialization in Burkina Faso faces several challenges including lack of labor due to migration of young people from rural areas to urban centers, access to agricultural inputs, as well as competition from Asia. Strengthening technical, logistical and organizational capacities of local stakeholders is necessary to overcome these constraints.

There is commonly no price premium for high quality rice. It is either sold as wholegrain, white, or parboiled rice. Primary processing (paddy processing) is the main alternative for adding value to rice in Burkina Faso. There are two types of primary processing. These are parboiling and milling. Parboiling is essentially carried out by women, known as parboilers. They process 52% of the national paddy production. Some of them are organized in a national union of rice parboilers. There do not seem to be any regulatory requirements to sell rice locally. Organically produced or fair-trade rice does not play a role in the sector. For rice, projects of the Ministry of Agriculture and other technical and financial partners support the actors in the acquisition of the technology by subsidies varying between 50% and 70%.

Since 2016, the GIC has been supporting the Ministry of Agriculture of Burkina Faso by disseminating innovations to improve the rice VC, including the “young service providers in agricultural mechanization" approach in four regions of Burkina Faso (Boucle du Mouhoun, Hauts-Bassins, Cascades and South-West) representing about 40% of the national territory. In general, rice and other cereals are threshed manually with sticks or on barriques/tree trunks. Due to the lack of labor and its high cost, farmers the GIC Project introduces a multifunctional threshing machine. This innovation aims to promote smallholder access to community-based agricultural mechanization services and create employment for rural youth (men and women), support youth self-employment and recruit other young people to help them deliver mechanization services. It also aims at minimizing threshing losses and increasing incomes for smallholder farmers and service providers.

8.2 Post-Harvest Losses

The African Postharvest Losses Information System (APHLIS) estimates postharvest losses at approx. 14% in the rice VC in Burkina Faso in 2021, with harvesting, threshing and winnowing as the main points of loss (harvesting/drying in the field 4.44%, threshing/turning 5.64%, storage 2.65%). There is no reliable data at the national level, but in view of the practices, losses during post-harvest operations are much higher than those given by APHLIS, and can often reach 30%.[10]

8.3 Innovation

<table>
<tr><th colspan="2">Brief Description</th></tr>
<tr><td colspan="2">The promoted measure is a multifunctional thresher that can process several crops including rice, maize and sorghum. The thresher is an autonomous machine manufactured locally that is mobile. The thresher is made of a cone feed hopper, a threshing chamber equipped with a cylindrical finger drum, a winnowing system consisting of a fan, a vibrating sieve or shaker, a motive energy transmission system (24 Horse Power diesel engine) using pulleys and belts and outlets for the recovery of clean grain and the rejection of residues. The threshing machine is mobile and moved from field to field to thresh the crops. PHL are reduced by decreasing the time crops stay on the field and processing time compared to manual threshing and therefore which makes them less prone to attacks by pests. The product is cleaner and the amount of broken grains and impurities are close to zero while the total losses are estimated at around 0,8% compared to 10% when done manually. This approach further allows smallholders to cope with labor shortages and is a viable source of income for young entrepreneurs.</td></tr>
<tr><th>Target</th><th>Target Group</th></tr>
<tr><td>Aims at improving the marketable quality of the product by reducing impurities (thereby increasing price per unit)
Aims at decreasing spoilage/waste (thereby increasing volume of marketable product)
It aims at creating employment for young entrepreneurs</td><td>The direct beneficiaries are young entrepreneurs whom offer the threshing services to smallholders. The indirect beneficiaries are smallholders, who end up with less PHL and a better quality product.</td></tr>
<tr><th>Geographical Location</th><th>Timeframe</th></tr>
<tr><td>Four regions of Burkina Faso (Boucle du Mouhoun, Hauts-Bassins, Cascades and South West) representing about 40% of the national territory</td><td>October 2021 to January 2023.</td></tr>
<tr><th colspan="2">Ownership</th></tr>
<tr><td colspan="2">The threshing service is offered against a fee to smallholder farmers, who do not possess their own mechanical threshing equipment. By identifying, training and providing young rural people under 35 years of age with mobile threshing equipment, they are able to set up a threshing service, which in turn increases the quality and quantity of threshed rice in rural areas.</td></tr>
</table>

[10] For an overview of potential reasons for PHL in the rice VC compare with 8.2 Mali

Framework Conditions

To optimize the location for providing threshing services that meet the requirements of small-scale producers and ensure profitability for service providers, it is essential to consider both geographical and market environment factors.

Geographic	Market
Location Specific Analysis	**Availability and Cost of Threshing Equipment**
The area in which the mobile threshing service is established should be within a rice producing area, where the distances between fields are relatively small as to avoid high costs for fuel and time being spent travelling from one field to the next.	Access to reliable and efficient equipment is crucial to ensure uninterrupted operations and meet the demands of small-scale producers, while managing the cost of equipment acquisition and maintenance is essential for sustaining a profitable business model and offering the service at an acceptable rate.
Market Proximity	**Labor Availability and Costs**
As the threshing is offered as a service on site, rather than selling a product at a specific market, the market proximity dos not play a role for the thresher. However, proximity to service providers for O&M is important as to avoid long interruptions when repairs are necessary.	The cost of labor directly impacts the profitability of the threshing service provider. Analyzing the prevailing wage rates and labor cost structures is important to ensure that it remains competitive while also covering labor expenses. The cost of labor can further impact the demand for threshing services. If labor is abundant or cheap, farmers may prefer to manually thresh their produce instead of hiring the threshing service
Last-mile Infrastructure	**Ability to Pay**
Road infrastructure is important for the thresher to be able to reach the fields. The better the road conditions and the smaller the distances between fields the better.	Income levels of smallholders should be analyzed to assess their ability to pay for threshing services. The economic constraints of the target market must be considered and competitive rates that align with the farmers' ability to pay offered. Threshing may be carried out by family labor, and the farmers therefore may be reluctant to pay for such a service.

The approach focuses on identifying rural youth under the age of 35. These individuals were then trained and equipped with threshing kits for agricultural mechanization. Their responsibilities include maintaining and repairing equipment, as well as providing threshing services to small farmers. The major challenge with this approach is that the procurement of mobile threshing equipment is not feasible for youth who do not have sufficient savings or capital. Thus, financing institutions will need to be involved in the process to provide the necessary funding.

The thresher is locally made, but obtaining spare parts such as grills is reported to be very difficult in the remote rural areas. Service providers for repair and maintenance are available. Mechanics were identified and trained to act as service providers but most of them still need capacity building. They handle more complex repairs and maintenance tasks, such as welding or manufacturing exchangeable parts. Additionally, they supply fuels, lubricants, and other spare parts, which is crucial due to the difficulty of obtaining such items in remote rural areas.

The famers themselves do no harvest large enough volumes to purchase the equipment themselves. Offering the mobile threshing on site replaces the manual labor which is usually more expensive and less efficient. The mobility and multi-crop capability of the service are key success factors. There is currently no significant competition except manual labor. While the primary clients analyzed for this service were small-scale rice producers, it is important to also consider corn, sorghum, soybean, and cowpea producers.

Business Model Canvas

<table>
<tr><th>Key Partners</th><th>Key Activities</th><th>Value Propositions</th><th>Customer Relationships</th><th>Customer Segments</th></tr>
<tr><td rowspan="3">-Thresher manufacturers
-Repair and maintenance service providers
-Finance institutions</td><td>-Threshing of rice (and other processing steps the equipment can do)
-Customer service (identifying and maintaining relationships9
-Equipment maintenance
-Transport from customer to customer</td><td rowspan="3">-Fast immediate threshing of rice on site
-Reduction of PHL due to less broken grains and less time the rice remains exposed to pests and diseases, humidity and theft on fields.
-Improved quality of the product as the process reduced impurities and broken grains
-Cheaper than employing manual labor</td><td>-Rice producers: Access to threshing as a service</td><td rowspan="3">-Small scale rice producers
-Producers of other crops</td></tr>
<tr><th>Key Resources</th><th>Channels</th></tr>
<tr><td>-Technology and equipment
-Skilled workforce
-Financial resources
-Partnerships and collaborations</td><td>- Farm gate purchases of service, Networking, social advertising and community building</td></tr>
<tr><th colspan="2">Cost Structure</th><th colspan="3">Revenue Streams</th></tr>
<tr><td colspan="2">-Capital costs for purchasing the mobile thresher
-Operating costs such as fuel and operational/labor costs
-Transportation costs for moving the thresher between fields of clients
-The technical expertise and management required to operate
-Developing and maintaining relationships with smallholder farmers</td><td colspan="3">-Payments for threshing services (rice and other crops)
-Payments for other operations the mobile thresher can do (ploughing, harrowing…)
-Engines of the threshing machines after the threshing period to operate water pumps for field irrigation</td></tr>
</table>

Cost Benefit Calculation

The CP is well advanced and has not just been able to train the target group and distribute the threshing equipment, but they have been able to carry out an economic analysis describing some key economic parameters. So far:

- A total of 43 young rural service providers have been trained in the use of threshing machines. The services they offer align with the needs of smallholder farmers in the western region of Burkina Faso, who expressed satisfaction with the grain quality and equipment efficiency.
- During the threshing season from October to February, each machine can process a minimum of 400 MT of agricultural products per year. This results in a profit of around 8 million FCFA. The threshers become profitable after 67 hours of use per year, a target that all service providers achieved in the previous season (average of 80 tons).
- Total percentage losses (broken grains and impurities) reduced from 10% to 0,8%.
- Break-even point of thresher is reached at 67 MT per year (average at 80 tons).
- The thresher enables farmers to cope with labor shortages and resulting high labor prices.

Based on the achieved results, other projects and programs have supported additional farmers in acquiring multifunctional threshers at subsidized prices. Farmers and farmer groups have been able to purchase these machines for their specific needs and services in their communities. The success of this approach can be attributed to several factors, including existing demand, the thresher's ability to handle multiple crops, its mobility, the careful selection and training of young participants, and the technical and managerial training they have received.

8.4 Conclusion and Recommendations

In conclusion, the intervention in Burkina Faso has proven to be a successful initiative that empowers young entrepreneurs to establish profitable businesses while simultaneously reducing PHL for rural rice producers. The functional technology and existing market provide a solid foundation for the intervention's future growth and impact.

Moving forward, it is crucial to provide support to these entrepreneurs in acquiring essential business management skills. Selection, training, and coaching of young entrepreneurs are vital prerequisites for the successful adaptation and scaling of the intervention. A vocational program that qualifies individuals as professional service providers should be considered enabling them to develop a comprehensive understanding of their operations and associated costs, avoiding the risk of mispricing their services and ensuring effective financial management. Furthermore, additional support should be directed towards enabling entrepreneurs to expand their services and reach a wider customer base (i.e. by including other crops).

For widespread dissemination of this innovative approach, continuous monitoring and improvement of technical and economic capacities among service providers are essential. Efficient maintenance services must be organized and structured to ensure the longevity and effectiveness of the equipment.

To scale up these activities, securing institutional support and working with banks and microfinance institutions to ensure the availability of appropriate financial products to finance equipment will be crucial.

9 Côte d'Ivoire – Cassava – Solar Dryers – Case Study

9.1 Context

Cassava is grown in almost all regions of Côte d'Ivoire. The major producing areas are in the central and northern regions of the country. The crop is primarily grown by smallholder farmers who use a range of production systems from traditional shifting cultivation to more intensive production systems. The average yield of cassava in Côte d'Ivoire is about 15 MT per hectare, which is relatively low compared to other African countries. This is partly due to the low adoption of improved varieties and agronomic practices.

Cassava is an important staple food, particularly in the northern and central regions of the country. But demand for processed cassava products used in the food and industrial sectors, is growing. Cassava processing involves several stages, including harvesting, peeling, grating, pressing, and drying. Most processing activities are carried out by women and youth using traditional processing methods such as manual grating and pressing. There is a growing number of mechanized processing units that use motorized graters and presses to increase efficiency and reduce labor costs. Processed cassava products include Attiéké, Fufu, Tapioca, and starch.

Marketing of cassava products is mainly carried out by small-scale traders who purchase the products from producers or processors and sell them to retailers or consumers. The market for cassava products is highly segmented, with different products and qualities sold in different markets. Garri, for example, is mainly sold in urban markets, while Fufu is mainly sold in rural markets.

Despite its importance, the cassava VC in Côte d'Ivoire faces several challenges, including low productivity, poor quality, and inadequate processing infrastructure, limited access to credit and markets, and weak institutional support. The lack of standardization and quality control in the market is another major challenge for the cassava VC in Côte d'Ivoire. These issues are compounded by the effects of climate change, which is causing erratic rainfall patterns and increasing the incidence of pests and diseases. Despite the challenges, there are also several opportunities for the cassava VC in Côte d'Ivoire, including the potential to increase productivity and quality through the adoption of improved varieties and agronomic practices, the development of efficient processing technologies, the substitution of wheat and the promotion of value-added products such as cassava flour, chips, and pellets. There is also potential for the cassava VC to contribute to poverty reduction and social inclusion by creating employment opportunities and improving the livelihoods of smallholder farmers and processors (often women) particularly through the adoption of innovative technologies.

The main factors and points of PHL in the cassava VC in Côte d'Ivoire are due to the short shelf life of the tubers (within 48 hours the tubers start to deteriorate). In addition, the peeling rate is high when the treatment is after 48 hours, which leads to further losses. Another crucial loss point is the extraction from the soil, if left in the soil for more than 24 months it causes lignification of the tubers. Thus, PHL are estimated between 15% and 40% in Côte d'Ivoire, depending on the location, time of harvest, and post-harvest handling practices.

9.2 Post-Harvest Losses

Step in VC	Activities	Inputs	Stakeholders	Potential Reasons PHL
Harvesting	Extraction from the field	Manual harvest using machetes or hoes	Farmers, laborers	If cassava is not harvested at maturity, tubers start to rot/mold under the soil. When tubers are harvested before maturity, the water content is too high and after maturity the tubers become lignified. Improper harvesting techniques also lead to losses due to root breakage or premature detachment of the roots from the stem.
Transportation	Transportation to processing sites or markets.	Vehicles (motorbikes, lorries…), fuel, baskets, sacks, crates, scales	Aggregators, processors, transporters, traders	During transportation, the roots can suffer mechanical damage from rough handling or excessive loading.
Peeling	Skin is removed as it contains cyanogenic glycosides	Peeling machine (manual or electricity/fuel powered), water, labor	Farmers, processors, laborers	Approximately 10% loss when cassava is not peeled on the same day as harvest
Washing	Washing to remove dirt, debris, and any remaining soil	Water, large vats or washing machines	Farmers, Processors	Water absorption, bruising, quality deterioration if water is contaminated
Drying	Peeled roots sliced to thin pieces, spread on trays for pre-drying, dryer to further reduce moisture content	Sharp knife or mechanical slicer, mats, traps, dryer, ovens, moisture monitoring equipment	Processors, Wholesalers	Over drying (leads to crumbling or breaking during transport), under drying (mold, decay) contamination (soil, pests, insects), weather related losses (rain)
Grinding	Water added to make a slurry, further processed depending on desired product	Mortar and pestle, or more modern equipment such as mechanical grinders	Individual farmers, processors, consumers	If cassava roots are not ground properly, there can be a significant loss of starch and other valuable components
Storage	Storing the harvested or processed cassava	Warehouse, storage facility, packaging materials,	Logisticians,	Sprouting, pests, diseases, shrinkage

9.3 Innovation

<table>
<tr><th colspan="2">Brief Description</th></tr>
<tr><td colspan="2">The promotion of direct solar dryers for the drying of cassava chips for flour production aims to reduce PHL, while creating additional market opportunities for cooperatives. The traditional method of drying cassava chips is done by placing them on plastic tarps in direct exposure to the sun, which leaves the tubers vulnerable to weather, dust, and animals. Mold growth is also a major risk, exacerbated by unpredictable rainfall patterns. The harvesting and processing of cassava is usually the responsibility of women, so the intervention mainly benefits women and supports them in their income-generating activities. The solar dryers are produced locally by the Institut National Polytechnique Félix Houphouët-Boigny (INP HB), using readily available materials such as iron, stainless steel, and sheet metal. The institute is also responsible for training women who are associated to cooperatives on the use of the equipment, conducting economic studies, and analyzing the final product. The dried cassava chips can be processed to Cassava flour and sold to i.e. local bakeries. Demand for this flour has been increasing in the past as prices for wheat flour surged in the previous years. To process the dried cassava in to flour a grinder is needed.</td></tr>
<tr><th>Target</th><th>Target Group</th></tr>
<tr><td>-It aims at reducing the high rate of losses during drying
-It aims at improving the quality of cassava pod flour
-The solar-dryers should reduce the time spent drying the pods (48h instead of 5-7 days)</td><td>As the project focused on the cocoa VC, the dryers were distributed to 9 cocoa cooperatives + 1 NGO (9891 members). These are not specialized in cassava, but this is the main activity of the women associated with the cooperative (around 13%). However, there are also cooperatives that focus on cassava.</td></tr>
<tr><th>Geographical Location</th><th>Timeframe</th></tr>
<tr><td>Southern Zone (Agneby-Tiassa, Sud-Comoé & District Yamoussoukro) and Western Zone (Cavally, Nawa & San-Pedro)</td><td>Dryers delivered in October 2022 and trainings on their use have taken place. Study to be conducted in summer/fall 2023</td></tr>
<tr><th colspan="2">Ownership</th></tr>
<tr><td colspan="2">Women's groups affiliated with the cooperatives also become owners of the equipment. Ownership is thus shared among the members of the cooperative or group. They sell cassava flour to individuals and to bakeries (who mix cassava flour with wheat flour). Training courses have already been set up for bakeries, as the substitution of wheat flour by cassava flour is a viable solution to the wheat supply crisis in Ukraine. The distribution of flour to wholesalers is still rare, as production is on a small scale.</td></tr>
</table>

Framework Conditions

To ensure the economic sustainability of the solar dryer intervention in the cassava VC, financing must be ensured, and market conditions analyzed.

Financial	Market
Access to Capital	Market Demand
Women cooperatives need access to capital to finance the purchasing of equipment, construction, and covering operational costs. Access to affordable loans, grants, or financial assistance programs specifically targeted towards women's cooperatives is needed.	A stable and sufficient demand in the local markets is required. Prices of dried cassava in line with the ability to pay by the local population and at the same time provide a reasonable return on investment for the solar dryer operators.
Monitoring and Evaluation Systems	Value Addition
Clear and transparent reporting on financial performance, impact, and outcomes can demonstrate the viability and potential of the operation, making it more attractive for investment or funding opportunities.	The market position can be enhanced by adding value to the dried cassava. This can be achieved through product diversification (e.g. baking flour), quality certifications, and creating unique selling propositions.
Financial Literacy and Business Skills	Market Linkages
A certain level of financial literacy and business skills including financial management, budgeting, record-keeping, and business planning is required to allow women to make informed financial decisions, manage funds effectively, and access external financing.	Strong market linkages are crucial. This involves building relationships with producers, buyers, processors, traders, and other relevant stakeholders. Developing reliable and long-term partnerships can ensure a steady market.

The project is working closely with INP-HB for the design and supply of the solar dryers, Economic studies and analysis of the nutritional quality of the finished product are currently conducted. One risk could be that consumers have a cultural preference for traditionally processed products. The most promising value addition is to process the dried cassava into baking flour as prices for wheat flour have substantially increased in the past years.

The dryer is locally produced and materials can also be procured locally. INP HB is currently the only official supplier in Côte d'Ivoire. Suppliers of similar models do exist and pilot tests envisaged. According to the CP, training services likewise exist in the region. The assumption is that more training providers will be established if demand rises as the equipment is easy to operate. The cost of acquiring solar dryers is with 500.000 FCFA (approx. 750 €) not too high. Nevertheless, women's groups in cassava processing face difficulties with the required financing. It is therefore an advantage that the women cooperatives are part of established cocoa cooperatives with sufficient capital. Other projects (such as “Promotion du Financement Agricole” (ProFINA) by GIZ and “Fonds Interprofessionnel pour la Recherche et le Conseil Agricoles” (FIRCA) implemented by the Ivorian government focus on linking cooperatives and women's groups with financial institutions. The financial framework conditions are thus generally favoring. Still, the main challenge is the lack of knowledge of bankers in the agricultural sector, resulting in high interest rates.

Business Model Canvas

Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
-Solar dryer suppliers -Training providers -Finance institutions	-Procuring cassava roots from own cooperative members or the market -Processing of cassava into flour -Selling the produce to customers	-Reduces PHL by drying the chips rapidly in a clean and dry setting -The quality of the cassava flour is improved and it reaches higher prices on the market -The equipment does not require electricity or fuel and is therefore an environmentally responsible way to process cassava without greenhouse gas emissions. -The equipment is easy to use and is therefore accessible regardless of education level	-Transactional selling the flour or chips to individual clients or bakeries (functional relationships based on superior quality) -Sales at local markets (one-to-many)	-Local markets -Bakeries -Wholesalers Traders
	Key Resources		**Channels**	
	-Technology and equipment -Skilled workforce -Financial resources -Partnerships and collaborations		-Networking -Social advertising, -Community building	

Cost Structure	Revenue Streams
-Capital costs for purchasing the solar dryer -Operating costs such as the raw material (cassava), packaging material and operational/labor costs -Developing and maintaining relationships with clients and smallholder suppliers	-Income generated from selling the cassava flour or dried chips -Potential of offering drying services to customers during down times

Economic Valuation

The intervention reduces PHL by processing cassava tubers at the ripe stage just after harvest which would otherwise be lost due to their limited shelf life. This ensures a better quality of the product by protecting it from external influences (dust, dirt, animals, etc.) resulting in less spoilage and waste and higher prices. The solar dryer is not exclusively designed for drying cassava, but can also be used for drying plantain (to obtain flour) or cocoa, vegetables such as chili or okra and also fruits can be dried.

Based on the information available at the time of the study, a hypothetical scenario was developed to evaluate the long-term profitability of a solar drying unit. In this, the traditional drying method is compared with that of a solar dryer at an assumed output of 12 MT of produce (48t of fresh produce / ratio 4:1):

	Traditional drying (side of the road)	Solar dryers (unit of 10 dryers)
Obtained market price	400 FCFA/kg	600 FCFA/kg
Net profits per year	510.000 FCFA	-545.760 FCFA
Cost of raw material per year	2.400.000 FCFA	2.400.000 FCFA
Cost of labor per year	1.440.000 FCFA	2.640.000 FCFA

The main issue is that the acquisition cost for 10 solar dryers for the unit is too high. Even if the solar dryers are operational for 10 years and no serious maintenance costs arise during this time, the unit will net losses on a yearly basis. In addition, next to general laborers which are also necessary in the traditional method, the solar drying unit is foreseen to employ a full-time office manager. Assuming this person is to be paid at the current national minimum wage, with all legal tax and social security contributions, this is a cost factor which contributes to the unprofitability of the activity. The other issue is the assumption, that the women produce sufficient cassava themselves and thus don't need to acquire it on the market. The simulation shows, that even if women produce sufficient cassava themselves, their overall cost of production should not exceed 20 FCFA/kg (which is 60% below the current market price for fresh cassava at 50 FCFA). These factors have to be acknowledged and studied in detail in the ensuing roll-out stage of the project.

9.4 Conclusion and Recommendations

Overall, the adoption of solar dryers is promising in terms of reducing PHL and improving the product quality. The equipment can be produced locally, however the investments costs are currently still too high to render the activity profitable. Demand for cassava flour appears to be existent. However, a steady supply of raw material must be ensured. Even if the cooperative members produce sufficient cassava roots, they should be able to do this at a highly competitive price, otherwise the value addition from the drying process will not be able to cover the necessary high investment and anticipated operational costs mostly driven by the labor costs for the trained staff. In the developed scenario, these factors combined render the business model unprofitable. As cassava is not cultivated as a cash crop, but to improve family nutrition, economic sustainability has not been the main reason to start this activity.

Operation and raw material costs incurred by the women when producing cassava roots without externalizing their own manual labor should be closely monitored. Necessary investments for up-scaling by banks or micro finance institutions are dependent on robust business models and they will be reluctant to finance any activity which can only be sustained if the women operating the units cannot be reimbursed adequately.

10 Zambia – Milk – Access Milk Testing – Case Study

10.1 Context

The dairy sector in Zambia plays a vital role in the country's agricultural landscape and rural livelihoods. With increasing urbanization, population growth, and rising disposable incomes, there is a growing demand for milk and dairy products in the country. Approximately 20% of the total milk produced in Zambia is channeled into the formal dairy market. This segment is primarily dominated by large and medium commercial farmers, who account for around 90% of its operations. On the other hand, the majority of milk production in the country is carried out by smallholder farmers, who engage in local and informal distribution.

In the Southern Province of Zambia, the price of milk varies significantly across different stages of the VC. At the farm gate level, the average price of cow milk stands at around 7.50 ZMW per liter, while cooperatives sell raw milk at the wholesale level for approximately 9 ZMW per liter. The final processed product, pasteurized milk, is typically sold in the market for an average price of 20 ZMW per liter. Milk prices are subject to fluctuations based on the season, with prices typically increasing during the dry season due to limited milk supply caused by low feed materials and water availability. Conversely, during the rainy season, milk prices tend to be lower due to oversupply, resulting in high PHL for farmers as off-takers reject poor-quality milk, often attributed to a higher incidence of mastitis. Off-takers offer a price premium of 9 ZMW for high-quality milk, which is categorized into three grades: A, B, and C. Grade A and B are considered good quality, with Grade A representing superior quality. However, Grade C milk, the lowest quality level, is not accepted by off-takers and is discarded during milk collection.

Challenges faced by smallholder farmers are primarily related to high input costs and low output prices. Zambia heavily relies on imports, particularly powdered milk and long-life milk, with Kenya and South Africa being major sources. Structural adjustments of the past have adversely impacted veterinary services, leading to exhausted livestock genetics and low productivity levels. The dairy sector in Zambia underwent significant changes in market structure after the privatization of the economy and dairy industry in 1991. The state-run Dairy Produce Board of Zambia, which previously held a monopoly over milk processing and the formal milk industry, was replaced by an increased number of processors with varying capacities. However, the market remains dominated by three companies, with Parmalat, an Italian multinational corporation, being the largest processor. These companies purchase the majority of milk from large- and medium-scale commercial operations and milk collection centers.

One of the main concerns is that the view companies hold significant control and influence over pricing and cooperatives often rely on one off-taker who in turn has monopoly power. Another issue is the power imbalance resulting from farmers not having any insights or understanding of the bacterial count testing conducted by processors forcing them to except the quality results and resulting prices offered. There are instances where processors fail to collect milk, resulting in losses for the farmers who are left to bear the consequences.

10.2 Post-Harvest Losses

Step in VC	Activities	Inputs	Stakeholders	Potential Reasons PHL
Input Provision	Raising dairy animals and feeding, breeding and regular health check-ups	Dairy animals (cows), animal feed, clean water, farm infrastructure, (agricultural extension)	Government of Zambia, Agro dealers, livestock breeders, Veterinary professionals, feed suppliers	Animals infected with diseases, poor nutrition leading, inadequate access to veterinary services, lack of proper farm management practices
Milking	Milking the cows	Milk cans or containers, water for cleaning	Small scale or commercial farmers	Delays in milk collection, improper handling and storage leading to bacterial contamination, lack of access to water and electricity (if cooling is needed)
Transport	Deliver milk cans/bottles to the cooperatives and further transporting	Vehicles, Refrigerated milk storing compartment for vehicles to store milk	Distributors, off-takers, marketing agencies, logistics providers	Temperature fluctuations during transportation, improper storing conditions in vehicles, improper handling of milk
Collection and storage (bulking)	Rapidly collecting milk and cooling it to preserve milk quality; milk is tested for its quality	Milk storing cans, cooling equipment, electricity for energy in cooling	Cooperatives, processors (off-takers), Logistics, Technicians for cooling facility installation and maintenance	Delays in milk collection, inadequate quality control measures, improper handling and storage leading to bacterial contamination, inadequate cooling facilities,
Processing	Processing of milk to dairy products (pasteurized milk, yogurt etc.) or sell it as raw milk	Milk testing laboratory, raw milk, water, energy and additives , milk chilling facility	Cooperatives and farmers , off-takers, Milk testing Laboratory technicians, Electric technicians,	Milk spoilage during processing, lack of access to processing equipment and technologies/laboratories
Packaging	Wrapping or putting pasteurized milk or milk products into marketable pack	Packaging materials, packaging equipment, labelling materials	Marketing agents, cooperative labor, packaging material suppliers	Poor packaging lead to deterioration of processed dairy products, poor temperature control of the facility /storing units
Marketing	Transporting, distribution and retailing of the finished products (raw milk or processed milk products)	Refrigerated transport vehicles, storage facility, marketing materials, skilled personnel	Farmer cooperatives, farmers, off-takers, local market traders, consumers, logistics providers, distributors	Inadequate market access for small scale producers, temperature fluctuation during transportation, lack of effective marketing strategies

10.3 Innovation

<table>
<tr><th colspan="2">Brief Description</th></tr>
<tr><td colspan="2">The intervention supported six cooperatives and the Laboratory of the Ministry of Fisheries and Livestock by providing motorcycles to efficiently carry out veterinary diagnostic laboratory test services for the milk. Off-takers usually pay a premium for milk grades (A&B) with C not being accepted. Previously they used to only include milk composition on grading but currently they rely on bacterial counts. One major issue tackled by the innovation is that cooperatives usually rely on a single off-taker having monopoly power. Prior to the intervention, milk testing could only be done in a few laboratories in Lusaka, which is more than 400 km away from the district where selected cooperatives are located. This resulted in a costly and time-consuming procedure that often resulted in spoilage or rejection of milk by the off-takers. When a new laboratory was established in Choma, Southern Province of Zambia, the milk samples were initially still transported there by the off- takers and often caused long delays and again lead to milk spoilage. Thus, to make the milk testing process faster and much more efficient, dairy farmer cooperatives were equipped with motorcycles for milk sample delivery. The intervention therefore supports food safety and consumer protection at local and addresses losses from poor milk quality through milk hygiene, post-harvest loss management and milk testing awareness among small scale dairy farmers in the Southern Province of Zambia.</td></tr>
<tr><th>Target</th><th>Target Group</th></tr>
<tr><td>-Aims at ensuring premium prices for the milk by improving the marketable quality
-Aims at reducing losses due to rejections by the cooperative or off-takers due to contaminants such antibiotics or disease-causing organisms</td><td>6 dairy farmer cooperatives + Laboratory of Ministry of Fisheries and Livestock (to improve the delivery of their veterinary services)</td></tr>
<tr><th>Geographical Location</th><th>Timeframe</th></tr>
<tr><td>Southern Province of Zambia
Districts: Mazabuka, Monze, Choma, Kalomo, Zimba, Namwala</td><td>August 2022 to December 2023</td></tr>
<tr><th colspan="2">Ownership</th></tr>
<tr><td colspan="2">The motorcycles are owned by the 6 cooperatives and the Ministry of Fisheries and Livestock Provincial Diagnostic Laboratory</td></tr>
</table>

Framework Conditions

The final dairy products from the farmer or cooperative or other involved processors should follow the guidelines and regulations of food safety (The Food Safety Act, 2019) and consumer protection (The Competition and consumer Protection Act 2010) authorities at local and national levels in Zambia. According to the Laws of Zambia, any dairy product sold in the market should fulfill the conditions of the Dairy Produce Marketing and Levy Act, which are implemented by the Dairy Produce Board. The Law shapes the wholesale dairy market of the country regulating the price of milk with reference to the quality standards set. Additionally, The Zambia Bureau of Standards provides for voluntary local certifications for SMEs, cooperatives if the cooperatives meet the minimum required requirements to be registered as a certified local supplier of milk.

The key service providers for this intervention are the cooperatives providing milk sampling services to enable their members' access to the Ministry of Fisheries and Livestock Provincial Veterinary Diagnostic Laboratory who will be providing the milk testing services. The most important operational resource is the fuel consumed for transportation and the trained personnel who must be capable of riding motorcycles and must have the necessary expertise in extension and milk hygiene. The servicing and maintenance of the motorcycles can be done locally. The idea is that that the costs of the intervention can be covered by a service fee or alternatively cross-financed though cooperative membership fees. The service can be extended with extension service for other topics, e.g., animal health, fodder production, agriculture, general hygiene and food safety depending on the knowledge of the extension officer. However, at the time of the study no concrete business plan had been developed yet. The motorcycles (ca. 2000€) and testing kits were fully financed by the GIC project. The operational costs could not be provided.

For further scaling and extending of the intervention the GIC project is currently collaborating with the Ministry of Fisheries and Livestock at provincial levels for the Training of Trainers and the development of training material. The Government of Zambia is currently supporting cooperatives through the Citizen Economic Empowerment Commission (CEEC), which are loans with a small interest the cooperatives can apply for. In addition to the community development fund, these funds support the investments projects which cooperatives wish to undertake to increase their economic gains. Such policy would be a favorable framework condition to roll out the intervention in wider geographic areas.

Business Model Canvas

<table>
<tr><th>Key Partners</th><th>Key Activities</th><th>Value Propositions</th><th>Customer Relationships</th><th>Customer Segments</th></tr>
<tr>
<td rowspan="3">-Dairy cooperatives
-Milk testing laboratories
-Veterinary professionals
-Suppliers of motorcycles
-Ministry of Fisheries and Livestock Laboratory</td>
<td>-Procuring and maintaining motorcycles for sample transportation and extension services
-Collecting milk samples from small-scale farmers and cooperatives
-Conducting veterinary diagnostic laboratory tests on the milk samples
-Providing extension services to dairy farmers and cooperatives
-Collaborating with the Ministry of Fisheries and Livestock Laboratory for quality assurance and accreditation</td>
<td rowspan="3">-Procuring and maintaining motorcycles for sample transportation and extension services
-Collecting milk samples from small-scale farmers and cooperatives
-Conducting veterinary diagnostic laboratory tests on the milk samples
-Collaborating with the Ministry of Fisheries and Livestock Laboratory for quality assurance</td>
<td>-Regular communication and engagement with dairy farmers and cooperatives
-Building trust and credibility through reliable and accurate testing services
-Providing personalized veterinary extension services and support
-Collaboration and coordination with the Ministry of Fisheries and Livestock Laboratory</td>
<td rowspan="3">-Dairy cooperative smallholder farmers
-Off-takers and milk buyers</td>
</tr>
<tr><th>Key Resources</th><th>Channels</th></tr>
<tr>
<td>-Graters, grinders, baking structures, and solar dryers
-High-quality cassava roots
-Sisal sacks or jute for water removal
-Knowledge and expertise in cassava processing
-Relationships and partnerships with farmer cooperatives, suppliers, and buyers
-Funding and financial resources for equipment procurement and operations</td>
<td>-On-site visits to dairy farmers and cooperatives for sample collection
-Motorcycles for efficient sample transportation
-Potentially digital communication channels (e.g., phone, email) for coordination and updates</td>
</tr>
<tr><th colspan="2">Cost Structure</th><th colspan="3">Revenue Streams</th></tr>
<tr>
<td colspan="2">-Procurement and maintenance of motorcycles
-Laboratory equipment and supplies
-Salaries and benefits for veterinary professionals
-Training and capacity-building programs
-Marketing and promotional expenses
-Administrative and operational costs</td>
<td colspan="3">-Service fees charged for veterinary diagnostic laboratory tests
-Consultation fees for extension services provided to dairy farmers and cooperatives
-Government or donor funding for supporting the intervention</td>
</tr>
</table>

10.4 Conclusion and Recommendations

The approach enables members of dairy cooperatives in Southern Province of Zambia to rapidly access the new milk testing facility in the region. Off-takers will have it difficult to push down prices, when the cooperatives know which milk quality they can offer. Farmer cooperatives can potentially reduce the rejection of milk by the off-takers, and increase their bargaining power to get price premiums thereby increasing their income. In addition, sick animals can easier be identified (milk testing for mastitis) and appropriate measures undertaken. The dairy cooperatives can potentially recover the variable costs for motorcycles by charging members a service fee (which includes veterinary and sample testing). However, as a concrete business plan has not yet been developed, it is not clear whether this service will be economically self-sustaining and whether member farmers are willing to pay for it in the long-term. It is therefore important to use the test-phase to evaluate the operational costs, upon which a business plan can be developed which looks at logistics optimization and the delivery of additional services such as farm-gate extension. If economically viable, the intervention has the potential to be scaled in the region. Investment in additional motorcycles will require financial loans from institutions while high interest rates pose a challenge. The project should therefore work on establishing partnerships and collaborations for funding from either the public or private side.

11 Malawi – Cassava – Solar Dryers – Case Study

11.1 Context

Cassava is a crucial crop in the economy of Malawi, contributing significantly to the country's economy and providing a source of livelihood to many smallholder farmers. The crop is a staple food for millions of Malawians and provides a significant source of carbohydrates, minerals, and vitamins. Furthermore, cassava is used as a raw material in various industries, such as food processing, pharmaceuticals, and textiles, making it a valuable commodity in the country. Cassava is a widely grown crop in Malawi, with many regions across the country producing it. Some of the most famous areas for cassava cultivation in Malawi include Karonga, Nkhata Bay, Lilongwe and Zomba. The intervention was implemented in two districts in the northern region of Malawi named Nkhotakota and Nkhatabay.

According to the project's data, in the previous year the average price of cassava achieved at the farm gate raised substantially from 40 MK per kg in 2020 to 150 MK per kg in 2022. The price at the consumer level likewise increased from 60 MK per kg in 2020 to 150 MK per kg. The price of fresh cassava in Malawi fluctuates throughout the year due to various factors such as weather patterns, supply and demand, and market conditions. Typically, cassava prices are highest during the lean season, which occurs between December and February when supplies are low and demand is high. During the harvest season, which occurs between March and May, cassava prices tend to be lower due to increased supply as farmers bring their crops to the market, especially when maize is in abundance. Prices may then rise again during the post-harvest period between June and August as supplies start to dwindle and demand increases. Price fluctuation due to the seasonal changes can be around 10%. In addition to seasonal fluctuations, cassava prices may also be affected by weather patterns such as drought or excessive rainfall, which can affect cassava yields and supply. Similarly, market conditions such as competition from other crops or changes in demand from processors and consumers can also affect cassava prices.

With reference to the PHL in the intervention region, the project estimates that about 30% of the production is lost due to the pest and disease infestations, use of recycled seeds (due to lack of improved varieties) and due to the use of labor-intensive utensils in processing stage.[11] This intervention was not part of the PHL booster but promoted under procurement of cassava processing equipment.

11.2 Innovation

<table>
<tr><th colspan="2">Brief Description</th></tr>
<tr><td colspan="2">Drying of cassava is an important step to increase its shelf life. Traditionally, farmers were drying the cassava on black plastic sheets in open space which puts it at high risk of contracting diseases as well as reduces its quality due to poor management. The innovation involves providing graters, grinders, baking structures and solar driers to farmer cooperatives. Cooperatives select mature cassava roots which are firm and without any bruises. The roots are then peeled with knives to prevent off coloring of the final cassava product. The peeled cassava is then washed to remove the dirt and impurities. Afterwards, the washed cassava is transferred to the newly introduced graters and grinders to grate the cassava roots into fine mash. It is then packed into sisal sacks or jute to remove excess water. Next, the pressed cassava mash is spread in a thin layer on a baking structure (in a black plastic sheet) in the solar dryer. After the drying process the cassava mass is milled to produce cassava flour. The final product is then sieved to remove other residues (like fibers).</td></tr>
<tr><th>Target</th><th>Target Group</th></tr>
<tr><td>-By providing cassava processing equipment it aims to help cooperatives add value to cassava and improve their economic benefits.
-Aims at improving the marketable quality of the product (increasing price per unit).
-Aims at decreasing spoilage/waste (increasing volume of marketable product).</td><td>The innovation targets farmer organizations/ co-operatives and individual farmers who grow and process cassava. VC actors include producers/growers, processors, value addition group, buyers and sellers. The harvesting and processing of cassava is usually the responsibility of women, so the intervention mainly benefits women and supports them in their income-generating activities.</td></tr>
<tr><th>Geographical Location</th><th>Timeframe</th></tr>
<tr><td>Two districts in the Northern region in Malawi: Nkhotakota and Nkhatabay</td><td>04/ 2023 – 09/2023, at the time of the study GIC procured construction materials and is training farmers on the use and construction of processing facilities to ensure sustainability.</td></tr>
<tr><th colspan="2">Ownership</th></tr>
<tr><td colspan="2">The equipment is fully owned by the cooperatives after handover.</td></tr>
</table>

[11] For the overview of potential PHL in the Cassava VC refer to chapter 10.2

Framework Conditions

To ensure the economic sustainability of the intervention several framework conditions are found crucial for the case of Malawi:[12]

Machinery supply and maintenance: Currently, the equipment and logistics are fully provided by the GIC. To rollout the innovation in a wider geographic area, the availability of local suppliers of solar dryer dealers, equipment manufacturers/ dealers is essential. The test-phase should be used to establish networks and partnerships with local suppliers. In addition, a plan to ensure obtaining the maintenance services of the installed equipment at regular basis for a reasonable price should be developed.

Market Demand and VC Development: Understanding market demand for cassava flour is crucial. In Malawi cassava is slowly replacing wheat due to escalating prices. The project estimates that the produced cassava flour is cheaper than wheat, which is the currently used means for baking and considered two times more expensive. A conducive market environment in thus expected. Developing strong VC linkages, including partnerships with distributors, wholesalers, and retailers, enhances market access and creates a sustainable market for the product. Currently, the main buyers of the Cassava flour foreseen are local bakers who are involved in value addition. Market research to identify potential buyers, such as food processors, retailers, and consumers, could help align production with market needs.

Quality Assurance and Compliance: The high-quality cassava flour produced needs to be certified by the Malawi bureau of standards and must therefore fulfill food safety regulations and quality standards. Implementing quality control measures throughout the production process, including solar drying, milling, and packaging, helps maintain consistent quality and product integrity. The cooperatives will be required to obtain licenses or register their operations with the appropriate government agencies. This could involve registering as a food processing business or obtaining specific permits related to food safety and hygiene

Capacity Building and Technical Assistance: Solar dryers are not a common practice in Malawi because most farmers and entrepreneurs are lacking the knowledge on health and sanitation and face a lack of access to materials and equipment. The project has established partnerships including the *Ministry of Agriculture* and *Ministry of Gender, Community Development and Social Welfare* which are providing human resources including agricultural extension development officers and community development assistants to train farmers on the proper use of the equipment.

[12] Relevant framework conditions can also be compared to the solar drier for Cassava in Côte d'Ivoire (Chapter 10.3)

Business Model Canvas

<table>
<tr><th>Key Partners</th><th>Key Activities</th><th>Value Propositions</th><th>Customer Relationships</th><th>Customer Segments</th></tr>
<tr>
<td rowspan="3">-Smallholder farmer co-operatives
-Suppliers of graters, grinders, baking structures, and solar dryers
-Agricultural extension services
-Local government and regulatory bodies
-Buyers of cassava flour
-Distributors and retailers</td>
<td>- Solar drying and milling of cassava roots to produce cassava flour
-Sieving and packaging the cassava flour
-Establishing relationships with distributors and retailers
-Marketing and promoting the solar-dried cassava flour
-Ensuring compliance with local government regulations and quality standards</td>
<td rowspan="3">-High-quality solar-dried cassava flour with extended shelf life
-Nutritious and safe product due to proper drying techniques
-Support for smallholder farmer cooperatives and local communities
-Access to a sustainable and marketable product
-Contribution to reducing PHL and food waste</td>
<td>-Training and capacity-building programs for farmer cooperatives
-Ongoing support and assistance in cassava processing techniques
-Collaboration and compliance with local government regulations and standards
-Establishing relationships with buyers for long-term partnerships</td>
<td rowspan="3">-Smallholder farmer cooperatives
-Local government and regulatory bodies
-Buyers of cassava flour (e.g., bakers, food processors, retailers)</td>
</tr>
<tr><th>Key Resources</th><th>Channels</th></tr>
<tr>
<td>-High-quality cassava roots
-Solar drying and milling equipment
-Packaging materials
-Knowledge and expertise in cassava processing and product quality
-Relationships and partnerships with suppliers, distributors, and retailers
-Funding and financial resources for equipment, packaging, and marketing</td>
<td>-Marketing and promotion through local networks, agricultural fairs, and online platforms
-Supply chain management for the distribution of cassava flour to buyers (currently mostly local bakers)</td>
</tr>
<tr><th colspan="2">Cost Structure</th><th colspan="3">Revenue Streams</th></tr>
<tr>
<td colspan="2">-Procurement of cassava roots
-Solar drying, milling, and packaging expenses
-Packaging material costs
-Marketing and promotional expenses
-Distribution and logistics costs
-Compliance and quality assurance costs
-Administrative and operational costs</td>
<td colspan="3">-Sales revenue from the solar-dried cassava flour
-Profit sharing with farmer cooperatives (if applicable)</td>
</tr>
</table>

11.3 Cost-Benefit Analysis

Implementing the innovation requires significant investments from the cooperatives. The costs for the main investments including the grater (ca 700€), Screw press (ca. 5700€), solar drier (ca. 3.300€) and mill (ca. 2000€) add up to nearly 12000€ which require significant funding and uptake of loans with high interests. Prices for high quality cassava flour in 2022 were with 400 MK per kg (ca. 0, 37€) estimated to be four times higher compared to raw cassava. The project estimates a production of up to 1,2 MT per day resulting in a potential turnover of up to 444€ per day. However, processing and marketing such a large amount of cassava on a daily basis will result in high operational costs especially for office and technical staff which will need support in logistics as well as training in production as well as food safety and hygiene. At the time of the study, a business plan including such information had not yet been developed

11.4 Conclusion and Recommendations

In conclusion, the intervention for solar-dried cassava flour in Malawi holds great potential for economic and social impact. The intervention encourages entrepreneurship among small-scale farmers, particularly women. The availability of cassava flour opens up opportunities for further processing and value addition, allowing farmers to explore diverse market channels such as bakeries with substantially higher rates compared to selling the raw material. To ensure the intervention's scalability, access to suitable financial products with reasonable interest rates from banks and microfinance institutions will be essential. This would enable cooperatives to expand their operations, invest in additional machinery, and increase production capacity. For this purpose it will be crucial to develop a detailed business plan in the coming months based on the data obtained during the test phase. The project should further concentrate on establishing strong marketing channels with the local bakeries and other potential wholesalers and retailers to be able to secure suitable financial products from banks and micro finance institutions at reasonable interest rates. Strengthened partnerships with relevant stakeholders, including government agencies, research institutions, and non-governmental organizations are also essential for the long-term success of the intervention.

12 Conclusion

The examined measures demonstrate promising outcomes in addressing economically significant PHL faced by smallholder farmers in the GIC project countries. These innovative approaches, conceptualized and piloted by different teams within a short timeframe, show potential for improvement in tackling the persistent challenges in the field of PHL. All of the introduced measures address relevant critical loss points by promoting specific technical solutions.

During the implementation of this study, certain limiting factors were identified that influenced its outcomes. It is important to acknowledge and address these factors in order to provide a comprehensive understanding of the study's findings.

The evaluation of the questionnaires confirmed the assumption that the level and quality of the data available at CP level varies greatly due to the differing stages of implementation at the time of enquiry. While some CP’s had successfully introduced their target groups to the technical innovation and managed to monitor and evaluate the use thereof, others were still in the process of building the capacity for roll-out. For the majority of CP’s, the necessary field data was not yet available. Even in cases where the desired data could be obtained in sufficient quality, a final assessment of the economic sustainability of these investments, requiring long-term adaption by the target group cannot be given with certainty. Consequently, a thorough economic analysis of the profitability of measures was not possible.

The heterogeneity in data availability combined with the fact that measures between the CPs differ greatly in their technical nature (from the provision of motorcycles to large cooling houses), their target groups (cooperatives or specialized service providers), and VCs (cassava, milk, rice, etc.) further limited a comparative analysis of the measures. Even if certain KPIs such as the NPV or IRR could be calculated for a number of the innovations, their comparison would not do justice to the complexity of what the GIC is trying to achieve at the different country levels. For example, women rice processor cooperatives in Mali face very different framework conditions and have different ambitions than mango producer cooperatives in Vietnam.

Nevertheless, recommendations can be derived from the results of the study. The long-term success of the intervention depends on embedding them in a comprehensive VC approach. While recommendations are provided for each business case and case study individually, there are some shortcomings that run through most of the promoted measures:

In general, the lack of understanding of the location of losses and associated factors within post-harvest VCs remains a major challenge to operationalizing PHL mitigation strategies. Analyzing where and why PHL occurs by identifying critical loss points can help guide interventions to those parts of the VC where reduction efforts are most impactful.

One of the major barriers identified is the lack of appropriate financial products, which hinders the scaling up of effective measures. The high interest rates and inadequate payback periods for loans often do not align with the business models of smallholder farmers and processors, making it difficult for them to access the necessary funds. To address this issue, it is crucial to provide financial institutions with field-proven economic data and sound business models. By equipping them with this information, they can assess the profitability and risks before developing suitable financial products, which are better aligned with the needs and capacities of smallholders and processors.

Furthermore, when promoting innovations aimed at improving the quality of agricultural products, it is essential to ensure the willingness of customers to pay premium prices. Developing a strategy to access these markets, as demonstrated in the examples of parboiled rice in Mali and mangoes in Vietnam, is crucial for the success of such initiatives.

Another finding is that many of the promoted technologies and processing facilities require large quantities of produce to be processed in order to make the investment financially viable. Yet, a strategy for a constant supply of raw materials at viable prices had not always been developed. This applies not only to crops such as cassava in Côte d'Ivoire and Malawi or paddy rice in Mali but also to processing services like cold storages in India, where a large enough customer base is necessary for the business to be sustainable.

When assessing the economic sustainability of investments, it is important to account for the full labor costs of smallholders in both production and processing. Omitting these costs can lead to a false impression of profitability and undermine the long-term viability of investments. Recognizing and incorporating labor costs ensures a more accurate assessment of the economic benefits and challenges associated with post-harvest loss mitigation measures.

Lastly, for the innovation to be sustainably implemented without continuous support of the GIC, the availability of technical equipment and tools, and technical services at a local level or the set-up of efficient supply chains for local procurement is crucial. Most of the CP's have developed a strategy to assure that the material can be sourced and maintained locally. This is critical for the longevity of the investments, as well as up-scaling and creates business opportunities for local input and service providers. Our discussions have shown that the need for such a strategy often became apparent only after the start of implementation, which in some cases led to delays. In future projects, this should therefore already be included in the planning stage.

On a final note, it must be emphasized that CP's have a wealth of experience and knowledge beyond the scope of this study. In light of this, it is highly recommended to explore opportunities for knowledge exchange between countries engaged in similar technologies or VCs. Such collaboration will enable the sharing of valuable insights and expertise, thereby promoting the adoption of effective solutions and facilitating ongoing progress in the mission to reduce PHL. By fostering a culture of collaboration and learning, stakeholders can benefit from the collective knowledge of CPs, leading to improved strategies and approaches in mitigating PHL. This knowledge exchange will play a crucial role in advancing the cause of reducing food losses, enhancing food security, and improving the livelihoods of individuals and communities worldwide.

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