Scoping and landscape analysis

Designing optimal (M)SME business models for the provision of postharvest processing services to smallholder farmers in Ethiopia

Shane Bohbrink(2), Helen Getaw(1), Akalu Teshome(1), Agdew Bekele(1), Tesfaye Leta(1), Anteneh Mekuria(1), Buddhi Lamsal(2), Kevin Agaziva(2), Alexandra Spieldoch(2), Stefano Perugini(2)

[1] Stichting Wageningen Research Ethiopia

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SWRE-RAISE-FS-working paper # 004

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Resilient Agriculture for Inclusive and Sustainable Ethiopian Food Systems (RAISE FS)
Addis Ababa, May 2023

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Postharvest processing is a significant contributor to losses in the value chain, dramatically reducing income potential and food security for farmers in Ethiopia. This report seeks to evaluate the challenges and opportunities for improved postharvest processing across a range of selected priority crops in Ethiopia.

Keywords: postharvest, processing, loss, Ethiopia

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Photo cover: Akalu Teshome

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Preface

Resilient Agriculture for Inclusive and Sustainable Ethiopian Food Systems (RAISE-FS) is a four-year program funded by the Dutch Embassy in Addis Ababa and hosted by Stichting Wageningen Research Ethiopia based in Addis Ababa, to bring about transformation in the Ethiopian food system. RAISE-FS will develop and implement a demand-driven and interdisciplinary approach to Research for Food System Transformation (R4FST) and as such contribute to the Government of Ethiopia's transformational agenda.

RAISE-FS adopts the food system approach as a Theory of Change (ToC), which helps in analysing the drivers and food system activities that contribute to the transformation of the food system by addressing leverage points, resulting in increased productivity, enhanced value chain performance, and improved human nutrition for food security while minimizing environmental impact and ensuring social inclusion.

The project aims to leverage transformation in Ethiopian food systems, covering the spectrum from food-insecure households and regions, to better-off households that are food-secure and can realize production surpluses, towards commodity commercialization efforts that contribute to rural and urban consumption demands and export.

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List of abbreviations and acronyms

DLS	Diffused Light Store
EGS	Early Generation Seed
ETB	Ethiopian Birr
GDP	Gross Domestic Product
FAO	Food and Agriculture Organization
KG	Kilogram
MCT	Multi-crop Thresher
MT	Metric Ton/Tonne
NGO	Non-Governmental Organization
RAISE-FS	Resilient Agriculture for Inclusive and Sustainable Ethiopian Food Systems
SNNPR	South Nations, Nationalities and Peoples Region
QDS	Quality Declared Seed
QT	Quintal (which equals 100kg)
PICS	Purdue Improved Crop Storage
PLC	Private Limited Company
PV	Photovoltaic
SWR	Stichting Wageningen Research
WCDI	Wageningen Centre for Development Innovation, Wageningen University & Research
WUR	Wageningen University & Research
USD	United States Dollars

Summary

Ethiopia possesses immense agricultural potential. And with two-thirds of the country's workforce engaged in agriculture, finding solutions that will improve productivity are essential. There is a significant need to unlock opportunities for smallholder farmers, who continue to face challenges that limit their productivity and income.

Postharvest processing is a major contributor to losses in the value chain, dramatically reducing income potential and food security for these farmers. This report seeks to evaluate the challenges and opportunities for improved postharvest processing across a range of selected priority crops in Ethiopia.

The opportunity assessment relied on a substantial amount of desk and field research to understand the current state of the postharvest landscape. Focusing on Oromia, Amhara, and the SNNP regions, the report identifies four areas in which micro/small businesses could be developed and sustained, thus generating economic activity, improving productivity, reducing drudgery, and improving livelihoods.

These four opportunities are:

1. threshing of cereals/grains/pulses (high likelihood of success)
2. potato storage, both seed and ware potatoes (some likelihood of success)
3. spice drying, particularly chilies (some likelihood of success)
4. poultry slaughtering (high likelihood of success)

For each opportunity, we evaluated the financial viability, market demand, and technical feasibility of implementing small-scale mechanization services.

For cereals/grains/pulses threshing, we saw evidence of such business models already working, albeit in pocketed locations using large and expensive equipment that is prohibitively expensive to most small-scale entrepreneurs. We were pleased to see a high awareness and demand for such mechanized services among smallholder farmers, who currently rely heavily on manual threshing with sticks and oxen to separate seed from stalk. In many cases, services providers were in such high demand that customers faced long waiting times. Our financial analysis indicates a strong likelihood that microentrepreneurs with the right equipment, the right technical support, and access to finance would likely succeed as businesspeople while providing a worthwhile service to the community. Our recommendation is to pilot an approach that tests two specific threshing technologies while seeking to partner with a long-term financing mechanism or guarantee program.

In the potato sector, we evaluated the storage of both ware (eating) and seed potatoes separately. Although these showed lower chances of financial viability due to the cost structure and cash flows of the businesses, the high postharvest losses (>50%) in the potato sector mean that this area deserves significant attention.

Improved potato seed is essential to increase the productivity of Ethiopian potato farmers. We recommend supporting existing seed producing cooperatives or seed producer farmers by linking them with the research institutes active in the country.

For ware potatoes, we see opportunity for smallholder farmers to store their crop in a small, local warehouse, which will allow them to reduce their postharvest losses and take advantage of the 40% price increase later in the season. However, there are open questions that need to be validated before any such solution is scaled. Will farmers be willing to pay up to 20% of the value of their crop? This is what we estimate is necessary for such a model to be financially viable to a storage entrepreneur. Perhaps more importantly, can farmers even afford to wait to sell later, or do they need the cash immediately? These are essential questions that are best answered during a pilot.

We also looked closely at the drying of spices, particularly ginger and red pepper chilies. Both crops are predominantly grown in the SNNP region of Ethiopia.

Unfortunately, we did not find a likelihood of success for ginger drying. The Ethiopia ginger industry has been decimated due to disease; as a result, the market is willing to pay double the price for imported ginger. Even if an effective drying system were to generate higher prices for ginger (and that is a big question), the fact that disease remains a significant issue to farmers means that efforts in the ginger sector should probably first be focused on tackling the disease issue (pre-harvest) before drying (post-harvest) can be prioritized.

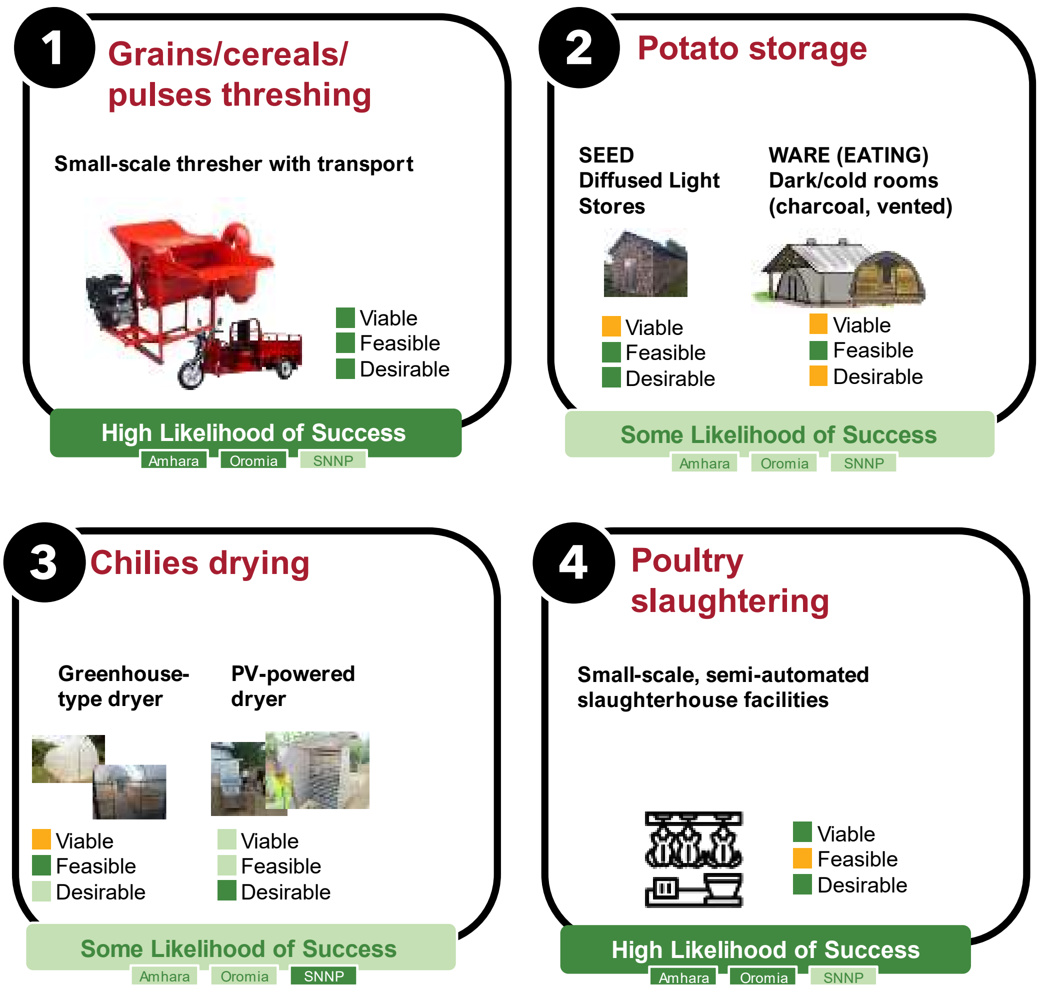
Red pepper chilies, on the other hand, hold more potential. The chili market uses a grading system to differentiate quality and price. Farmers must dry their chilies to sell on to the market, and this is currently done in the sun with high exposure to dust, dirt, and livestock. As a result, farmers often sell their chilies at

a lower grade and earn less money. We see potential for farmers to access drying services that result in higher-quality chilies and therefore higher prices. We believe this is possible because traders can also sell the chilies at a higher price, too – creating a potential win-win for farmers and traders alike. We have identified both greenhouse-type warehouses and photovoltaic (PV) powered dryers as potential technology solutions. We propose that these are piloted and tested using a business model in which a farmer pays a percentage (estimated around 10%) of his or her chili crop for the service, with overall price improvement potentially more than 50% for the farmer.

Finally, poultry slaughtering also presents an opportunity to support local chicken farmers while reducing dependence on poultry meat imports. At first glance, poultry does not seem to be a logical business opportunity. Ethiopians are some of the lowest consumers of poultry meat on the planet (2.5 kg per capita, per year), but demand is still high in urban areas, particularly among catering companies, restaurants, and hotels, which need chicken meat that has been processed in sanitary conditions. We looked at the potential for slaughterhouses to serve as toll processors (charging a fee per chicken slaughtered) and as traders (buying chickens and re-selling the meat) and found both to be viable, as long as an adequate supply of chickens were available.

This large amount of research, creative brainstorming, and quantitative analysis has helped us understand directionally which areas hold the most opportunity and what it would likely take to make them succeed. But to know for sure, they must be tested. All business models will require trial, error, and reconfiguration. Entrepreneurs will need training and support, and the barriers to finance must be overcome. Technology must be selected carefully, and it may take time to make the necessary modifications that will make them useful without losses or downtime.

RAISE-FS, with support from a technical expert like Bountifield, is in a good position to serve as the steward for these opportunities. By implementing these small-scale mechanization services, we can help smallholder farmers improve the quality and value of their crops, create new economic opportunities including local jobs, and ultimately lift people out of poverty.



Background

RAISE-FS and Bountifield identified an opportunity to work together to build upon previous work of RAISE-FS and other partner programs to: (1) research the current state of the postharvest technology landscape in the country, (2) explore and validate the technology for strategic crops and geographical areas, and to (3) design optimal business models for microbusinesses that can use fit-for-purpose postharvest technologies, including the potential financing strategies for making such businesses succeed.

Stichting Wageningen Research (SWR) Ethiopia

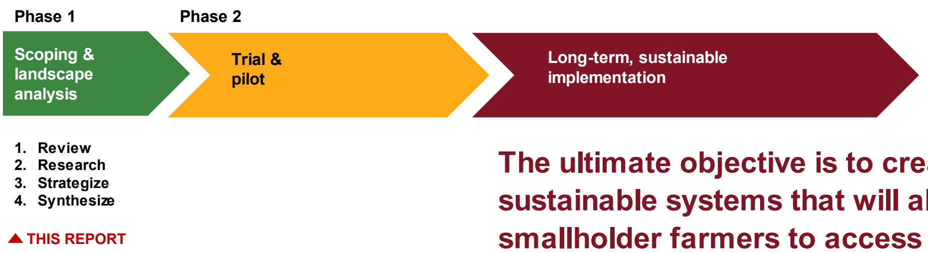
Resilient Agriculture for Inclusive and Sustainable Ethiopian Food Systems (RAISE-FS) is four-year research for development program with a mission to leverage transformation in Ethiopian food systems covering the continuum from food insecure to the better-endowed households and regions in effort of realizing production surpluses, commodity commercialization, and food and nutritional security in a sustainable manner. The program is overseen by Stichting Wageningen Research (SWR), an international NGO.

Bountifield International is an international NGO specializing in postharvest technology solutions for smallholder markets in Africa. It works to fill gaps in African postharvest technology markets that have been neglected or underserved, including partnering with African equipment suppliers to offer quality tools that Bountifield has vetted and tested for the market. It also includes working with local partners to develop rural entrepreneurs, women and youth, as fee for service providers.

Objectives, Scope, and Approach

This report is intended to be the first phase of a multiple phased approach, with a second phase to trial and pilot based on the findings in this report.

The ultimate objective is to create sustainable systems that will allow smallholder farmers to access postharvest technologies that will increase output, improve quality, and reduce drudgery.



The ultimate objective is to create sustainable systems that will allow smallholder farmers to access postharvest technologies that will increase output, improve quality, and reduce drudgery.

The scope of Phase 1 focused on regions where commodities and value chains have already identified by the RAISE-FS team. As part of the process, we selected a more targeted set of crops and technologies to maximize the ability to identify the best possible business model/technology solutions and therefore increase likelihood of long-term success.

Research, interviews, and data collection were conducted by the team, including evaluation of key value chains in the following regions:

- **Amhara Region:** Sesame, soya, mung, sorghum, teff, potato
- **Oromia Region:** Lentil, field pea, fava, potato, poultry
- **SNNP[1] Region**: Ginger, pepper

While we conducted interviews at the regional level, we evaluated the potential to apply the information across multiple regions, where applicable.

[1] SNNP stands for the Southern Nations, Nationalities, and Peoples' Region

Section 1: Ethiopia and Its Food & Agriculture

1.1 Ethiopia and agriculture

Agriculture is the backbone of the Ethiopian economy, accounting for roughly 37% of the country's GDP[2] and employing over two-thirds of the workforce[3]. Over 120 million people[4]—nearly one-tenth of Africa's population—live in this vibrant and culturally and ecologically diverse country. Its farmers produce a range of agricultural products including cereals (such as maize, teff, wheat, sorghum and barley), pulses (such as chickpeas, fava beans and lentils), oilseeds (such as soya bean and sesame), and horticultural crops (such as fruits and vegetables). The country is also a major producer of livestock, including cattle, sheep, and goats. Coffee is its largest export crop[5].

Despite the importance of agriculture to the country's economy, low productivity remains a significant challenge. The lack of modern farming techniques, limited access to markets, unavailability of credit and private investment, and limited extension services are potential inhibitors. The country is also vulnerable to natural disasters such as droughts, land degradation and floods[6].

Postharvest and agro-industrial processing continue to be underdeveloped. Farmers remain dependent on manual postharvest techniques, and storage solutions are limited. Value-add solutions at the industrial level are equally inadequate. Despite Ethiopia's significant dependence on agricultural production, only 5% of the country's GDP comes from agro-processing[7].

The government and international development agencies continue to seek solutions that will support Ethiopia's development. An estimated USD 3.5 billion in development aid has gone to Ethiopia in recent years[8]. Gates Foundation alone has contributed nearly USD 800 million to agriculture and social initiatives[9]. Collectively, projects have included increasing investment in irrigation infrastructure, providing farmers with improved seed varieties and other inputs, and expanding access to markets and credit. Agro-industrial production has risen in priority[10].

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[8] Borgen Project. "How Foreign Aid Helps Ethiopia." The Borgen Project, Borgen Project, 2023, https://borgenproject.org/how-foreign-aid-helps-ethiopia/.

[9] Bill and Melinda Gates Foundation. "Ethiopia." Our Work, Bill and Melinda Gates Foundation, n.d., https://www.gatesfoundation.org/our-work/places/africa/ethiopia.

[10] United Nations Industrial Development Organization. "Country Brief Ethiopia." United Nations Industrial Development Organization, 2020, https://www.unido.org/sites/default/files/files/2020-11/Country_Brief_Ethiopia.pdf

1.2 Climate and agro-ecological Zones

Due to its contrasting geographies, particularly wide-ranging elevations, Ethiopia has diverse agro-ecological zones, each of which has its own unique climate, soil type, and agricultural potential[11]. These zones include[12]:

1. **Bereha:** Hot lowlands, <500 meters. In the arid east, crop production is very limited; in the humid west root crops and maize are largely grown.
2. **Kolla:** Lowlands, 500-1,500 meters. Sorghum, finger millet, sesame, cowpeas, and groundnuts.
3. **Woina Dega**: Midlands, 1,500-2,300 meters. Wheat, teff, barley, maize, sorghum, chickpeas, and haricot beans.
4. **Dega**: Highlands, 2,300-3,200 meters. Barley, wheat, highland oilseeds and pulses.
5. **Wurch**: Highlands, 3,200-3,700 meters. Barley is common.
6. **Kur**: Highlands, >3,700 meters. Primarily for grazing.

Oromia, Amhara, and the SNNP are significant regions for agriculture in Ethiopia. They are home to a majority of Ethiopia's population[13], including its smallholder farmers. They have large amounts of fertile land, abundant water resources, and favorable climates for crop production. As a result, these regions are the primary producers of cereals, legumes, oilseeds, and horticultural products.

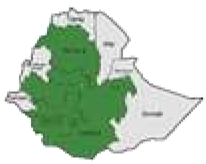


Figure 1: Production areas for major crops[14]

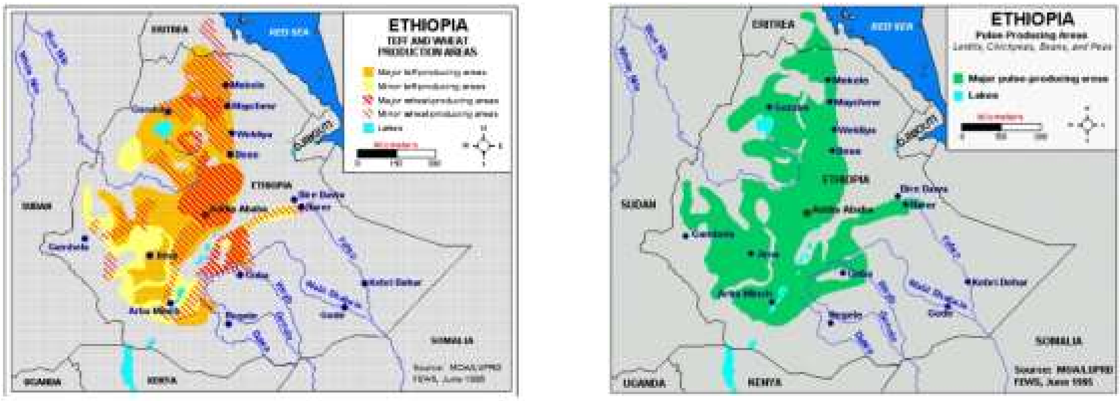
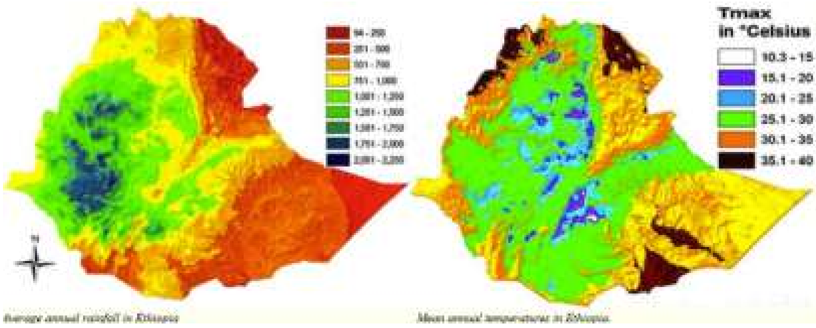


Figure 2: Average annual rainfall and mean annual temperatures[15]



[11] Hassen, Ibrahim, et al. "The Rural-Urban Transformation in Ethiopia." ResearchGate, 2013, https://www.researchgate.net/publication/265527316_The_Rural-Urban_Transformation_in_Ethiopia#pf10

[12] "Crops and Agro-Ecological Zones Total." Dereje Gorfu and Eshetu Ahmed. Ethiopian Institute of Agricultural Research Accessed 15 Mar. 2023. https://prrp-ethiopia.wur.nl/index/component/phocadownload/category/8-%20crops%20and%20agro-ecological%20zones%20total%20-%20dereje%20gorfu2770.pdf?download=51

[13] "Ethiopia: Population Density (People/Km²) - 2020." ReliefWeb, 2020, https://reliefweb.int/map/ethiopia/ethiopia-population-density-people-km-2020.

[14] "Crops and Agro-Ecological Zones of Ethipia." Dereje Gorfu and Eshetu Ahmed. Ethiopian Institute of Agricultural Research Accessed 15 Mar. 2023. https://prrp-ethiopia.wur.nl/index/component/phocadownload/category/8-%20crops%20and%20agro-ecological%20zones%20total%20-%20dereje%20gorfu2770.pdf?download=51

[15] "Ethiopia Weather." National Parks Worldwide, 2023, https://www.nationalparks-worldwide.com/eaf/ethiopia/ethiopia-weather.html.

Ethiopia is vulnerable to changes in rainfall patterns, temperature, soil degradation, and pest outbreaks, which can have serious impacts on Ethiopia's agriculture[16], creating negative consequences on the country's economy and its people. For example, studies have shown that a 1°C increase in temperature can reduce global wheat yields by 6%[17], with likely greater impact in low-yield locations. According to the Food and Agriculture Organization (FAO), an estimated 8.3 million people in Ethiopia need assistance due to drought-related crop failures and livestock losses[18].

1.3 Market dynamics and key trends

For the past decade, the Ethiopian economy has undergone significant growth and transformation. The country's GDP grew an average of 11% per year for the past decade[19], leading to increased job opportunities and improved living standards for many people in the country. However, much of this growth was driven by the services sector, particularly in financial services, real estate, and retail trade[20].

In addition, the development in the past decade has been from a low base. 2021 per capita GDP is USD 2,600, putting it 33rd in Africa.[21] The economy has taken a significant hit since the conflict in Tigray began in November 2020[22]. Inflation now hovers around 35% per year, well above its low of 10% in early 2019[23].

The government continues to try to find economic growth and focus has re-shifted back to agriculture, manufacturing, and exports. The government has announced billions of dollars in investments to create industrial parks and export processing zones, including 17 "agro-industrial growth corridors"[24]. In September 2022, the country preliminarily approved the entry of foreign banks[25]. Large construction projects continue where there are not security issues, particularly in Addis Ababa[26].

But these security issues in Ethiopia should not be overlooked, including their impact on smallholders and entrepreneurs, particularly those importing or exporting goods from the country. For example, the gap between the official exchange rate (52 birr = 1 USD) and the black-market rate (90 birr = 1 USD) is huge. Importers purchasing in USD are obligated to follow the official exchange rate, and so seek backdoor ways to trade USD with exporters. Bankers and other brokers, we are told, are informally connecting importers and exporters for a fee.

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[26] Odula, Tom. "Ethiopia's economy struggles as war reignites in Tigray." AP NEWS, Associated Press, 7 July 2023, https://apnews.com/article/africa-economy-government-spending-kenya-826141a7a692574d9609462d2549bffb.

Section 2: The Current Landscape for Postharvest Service Provision

Our researchers found varying availability of mechanized postharvest processing services depending on the location and crops. In the cases where services were available, they were confined to particular crops (e.g., wheat, barley, soybeans, teff, and maize). Some crops (e.g., pulses) had no mechanization services available at all.

2.1. Key themes across the sector

Economic Dynamics

Foreign exchange issues and inflation are important economic considerations for any business model. For example, when evaluating equipment purchases, the black-market exchange rate is nearly double the official exchange rate, which makes it difficult for most day-to-day businesspeople to import goods at affordable rates[27].

Equipment

Most of the machines we encountered were large-scale imported threshers requiring tractor pull and power. However, some locally manufactured threshing machines were much smaller and could be pulled on a trailer. Given that these are locally manufactured, the manufacturers are likely creating a more fit-for-purpose product that can be easily transported with smaller volumes. Despite these design improvements, we heard from both operators and farmers that the locally designed machines did not perform well.

Equipment Suppliers and Manufacturers

There are a few existing suppliers, some with branches in multiple cities (e.g., Mamaye Group, Woreta International Business Group). Some government parastatals like Amhara Metal, Machine, Industry Technology Enterprise are involved in manufacturing of postharvest technologies.

Inventory appears to be on-demand or irregular, potentially a result of foreign exchange issues and lack of access to capital. None sold their machines on credit.

[27] For the purposes of this report, we conducted all analysis in Ethiopian Birr (ETB) using an exchange rate of ETB 50 to USD 1 on the assumption that any official and formalized projects would use this rate. However, as the black market rate is ETB 90 to USD 1, it is important to be aware of the risk that not using the official rate could invalidate a significant portion of the analysis, particularly the investment/capex cost of any imported equipment.

Traders and Offtakers. 	Local traders are prevalent, operating mostly informally. Surprisingly, most farmers take their crops to market rather than any traders going directly to them. The exceptions we saw were with ginger and soybeans. We met a large-scale ginger trader supplying local farmers with planting materials in exchange for offtake (ginger planting materials are important, especially now, given the disease issues). The same was true for soybeans, where farmers received inputs in exchange for offtake. This makes sense given the growing soybean market.
Service Providers 	In multiple regions there was evidence of wealthy individuals/ entrepreneurs buying locally produced and imported machines for threshing crops such as soybeans and teff, and then employing local youth to operate the machines, with these youth taking ownership of the machine once the original cost of the machines was paid back from income. This seems to be a good incentive structure because in traditional employment models there is always a risk that the operators siphon the revenues to themselves and take little care of the machines. In all cases, maintenance seemed to be important; however, they lamented that major technical faults had to be fixed by a technician from Addis Ababa, and delays in fixes led to downtime.

2.2. Key themes by crop

Teff. Currently, there appears to be a gap in the technology used locally that allows optimal processing of teff and wheat together (and possibly sorghum and barley), which could optimize the capex costs of machinery. We believe that operational fine-tuning of equipment can make it possible to achieve best performance for both crops (e.g., flexibility of sieve size, secondary blower, etc.).

Soybeans. Soybean production is thriving, driven by high demand from buyers (and therefore high prices). Many farmers are switching to soybeans for the first time. Some expressed surprise when after harvesting soybeans they did not realize the difficulty of threshing. Improving postharvest opportunities for soybeans will be important, if not essential, to creating a successful soybean ecosystem.

Munga, Fava, Lentil, Chickpea. These pulses are relatively complex to harvest and thresh. All are important staple and cash crops for farmers. Low volumes of these crops make it difficult to justify business models on their own, but potentially pairing them together with multi-crop threshing with added features like interchangeable sieves, shaker etc. could improve the viability of the business.

Potatoes. These tubers suffer from significant postharvest losses. Farmers do not follow good storage practices. Most pile the potatoes on the floor of their homes, which leads to infestations and moisture issues. The issue of postharvest storage for potatoes is that (1) there are different storage requirements for seed and ware potatoes therefore requiring two different storage solutions, and (2) although on-farm storage solutions are relatively low cost (eg, not requiring mechanization), there is little evidence of any service provision happening that allow farmers to hold their inventory until a later date. Therefore, the business models need to consider that such storage solution would either be for a businessperson to buy and hold, or we need to see a culturally agreed system where farmers pay someone to hold their crop.

Spices. Farmers, fearing the disease, quickly sell their ginger ‘wet’ rather than allowing it to dry, which gathers a higher price and would allow them to defer their sales for later times of year. This is similarly true for pepper, which is an important spice ingredient. Both would benefit from a drying system more accessible to farmers and/or local traders. Significant and persistent aflatoxin issues might be overcome with improved drying techniques.

Poultry. This is a unique value chain compared to the others because it is the only one involving living animals and it requires a cold chain. At first glance, poultry does not look appealing because of its limited importance in day-to-day diet, however, chicken is culturally important and in high demand during holiday seasons. Aside from the holidays, Muslim fasting seasons, the growing food service sector, and tourism also drive demand for poultry products. Small-scale farmers who raise chickens have limited access to safe and efficient slaughtering facilities. There also appears to be a preference for butchering chickens at home, which has implications on any service-based business model. Nevertheless, traditional slaughterhouses do exist, and if pricing and other dynamics such as available supply were met, they could likely be replaced with safer and more efficient facilities.

2.3. Example area with postharvest services – Godono

Godono *Kebele*, Ada'a *Woreda*, Oromia Region

In the Oromia Region, for example, the Godino *Kebele* of Ada'a *Woreda* appeared to have a nascent but burgeoning postharvest service ecosystem for wheat and teff. The state of this economy appeared to be a result of a larger-scale farmer-cum-entrepreneur ("the richest man in the area") who purchased thresher machines and then hired youth to operate portable threshing machines. The business was started after the farmer purchased a small portable thresher[28] for his own use, and then recognized the opportunity to provide such services for the rest of the community.

[Of note, this area is just a few hours' drive from Addis Ababa. It is possible that mechanized services adoption could first occur closer to this city due to access to capital, knowledge, and equipment.]

The entrepreneur made a form of lease-to-buy agreement whereby the youth were employed by the entrepreneur until such a point that the incomes covered the cost of the machine, and the youth workers became the owners of the machines. This appeared to be an effectively-structured incentive system. The youth stated they were motivated by profit and that by declaring the income to the entrepreneur, they would more quickly become the owners of the machines.

In this scenario, fuel and maintenance costs were covered by the machine's owner, with the youth being paid a daily wage. The youth also said that in some cases they would rent the machine, pay for their own fuel and maintenance, and then earn based on profit. In cases where major maintenance was required, the owner would cover the costs.

According to our interviews, the youth could become owners after 2-3 seasons of work. They also expressed an interest in buying machines on credit if such financing and machinery were to be available, which is currently a challenge.

Our researchers were told that the thresher (excluding any small tractor or trailer to transport the machine) cost ETB 150,000 (USD 3,000) two years ago[29]. Fuel consumption of the thresher is 15 liters per day. Service providers in this area currently charge ETB 300 (USD 6.00) per QT for wheat and ETB 400 (USD 8.00) per QT for teff, as teff threshing is slower and more cumbersome than wheat threshing. The threshing season lasted 1-2 months in line with the harvest season, depending on the area of the cultivated crops of the *kebele* and the number of available threshing machines providing such services.

[28] The specific model is not known, but it was purchased at the Melkassa Agricultural Research Center, which has a department of engineering for R&D. It was likely paired with a motor purchased from Addis Ababa.

[29] It is somewhat difficult to adjust for this price in today's rates due to the high price inflation and currency depreciation; however, with inflation at 20-30% per year, the cost is likely significantly higher in today's figures.

Figure 3: Youth delivering services of wheat and teff threshing at Godino *Kebele* of Ada'a *woreda*

In the same area, cooperative-based service providers were also available. These cooperatives tended to have lower prices for their services[30].

More staff (5-6 laborers) were required for teff than for wheat (specific number unknown) because wheat easily feeds through the machine and comes out cleaner.). Staff were paid ETB 300 (USD 6.00) per day, plus meals.

Farmers in this area complained that the teff output was of poor quality. The threshing machine did not clean the teff seed from straw and chaffs, it simply threshed and provided uncleaned seed and thus, forcing farmers to winnow and clean the seed from chaffs. This was not an issue for wheat. In essence, the machines handled wheat significantly better (throughput speed and output quality) than teff, and therefore would likely always be favored over teff. Although we do not have specific details of the model or its design, it is likely that the thresher was designed for wheat and adapted for teff without proper setup (e.g., sieve, blower speed, etc.). Given that teff and wheat share the same harvest season, in this scenario the machine would likely be prioritized by the machine operator for wheat unless the price were still at a point that was satisfactory for both operator and teff customer.

Farmers said that they did not face issues such as service provider breakdowns, potentially because the equipment was relatively new. However, the machine did of course occasionally still have breakdowns. Simple breakdowns could be repaired by the operators who had some basic maintenance skills, but if the machine required major maintenance, they would call a technician from a nearby city (e.g., Bishoftu or Addis Ababa). Sometimes they also took the machine to a nearby garage for maintenance such as welding.

In the current model, the portable machines were positioned nearest to people’s homes, which is where farmers were piling and temporarily storing their unthreshed crop. Such homes were situated together in *kebeles*, the smallest administrative unit in Ethiopia. According to our researchers, most farmers would transport their harvest wheat and thresh by stacking it on top of donkeys or horse carts (and very rarely, camels[31]) (see Teff section) at a cost of ETB 500-900 (USD 10.00 – 18.00) per ¼ of a hectare.

According to our researchers, demand for such threshing services exceeded availability. Farmers would book an appointment with the service providers in advance by calling them directly, sometimes even paying a broker. Oftentimes, our researchers were told, the customers were unable to choose which service provider would come because service providers in the *kebele* are so few, so farmers contact any available service providers that would be willing to come to the *kebele*. In most cases, there is a waiting time for farmers to get the turn to thresh their teff and wheat. The price for the service would be set by the owner, but farmers in a group would negotiate to get a fair service provision price.

Our interviews indicated that farmers had a strong willingness to start mechanized services themselves, but the initial cost of the machines and ability to operate them properly were insurmountable hurdles. They specifically lamented that the government was not able to support them[32].

[30] Internal research

[31] In rare cases, in a place where camel is available, farmers can take more crop loads at once than donkeys. In this rare case, the owner of the camel will request a payment of ETB 500-900 to transport teff harvested from area of 1/4 of a hectare.

[32] The government has recently prioritized agricultural mechanization and reduction of postharvest losses. For example, agricultural machinery can be imported duty-free; however, this is usually one step away from farmers, who either are unaware of this opportunity or (more likely) do not have the capital to purchase the equipment to begin with.

2.4. Example area with postharvest services – Chafe Donsa

Chafe Donsa town of Gimbichu *woreda*

Located on the other side of Addis Ababa to the southeast, our researchers met with youth service providers in Gimbichu. They were also focused on wheat and teff. The youth had a similar employ-to-buy model where a rich man in the area purchased the equipment. The youth provided the services only during threshing periods whereas in offseason they were supporting their family work and participated in farming.

According to the operators, the machine threshed 64 QT of wheat and 16 QT of teff per 8 hours (a rather large-capacity machine).

The customers were farmers found in and surrounding *kebeles*. Researchers indicated that customers expressed interest in these services to reduce their workloads, complete timely postharvest, and improve their grain quality. But they complained that it usually required additional effort to for teff: cleaning the husks, removing the shard stack, and filtering the seed from stone/soils.

Farmers paid for services based on the availability of cash. Farmers who had sufficient cash available would pay at the time of service. Most farmers, however, would pay after the service was delivered at the point of selling the commodity. It is unclear if farmers therefore felt pressured to sell their commodities earlier to raise cash, thus losing out on market price increases that would likely occur during off peak season. Interestingly, in other countries (e.g., Ghana) service providers would often take a percentage (10%) of the threshed product in lieu of payment[33]. When inquiring about this in Ethiopia, we understand that this was not customary and likely not palatable to the farmer. However, in some cases the price of threshing was roughly equivalent to 10% of the market price, meaning that this was more a psychological barrier than a truly financial one.

Recently, the customers paid ETB 300-400 (USD 6.00-8.00) per QT for wheat and teff threshing.
Minor servicing and maintenance for the machines was done by the youth operators. However, the more serious maintenance was done by technicians from Addis Ababa and Adama cities. In the event of major mechanical issues, service providers would be left idle until the technician arrived. This sometimes took long periods of time (specific amount of time unknown). Operators said that threshers usually required minor maintenance every five months.

[33]Bountifield research and experience in Ghana

Figure 4: Threshing teff using machine at Chafe Donsa town of Gimbichu woreda

2.5. Additional threshing postharvest services examples

It is important to note that we encountered teff threshing services in other parts of Ethiopia as well, and in at least one case believe that the equipment resulted in a satisfactory output for farmer. For example, Sasakawa Africa Association- Ethiopia (more commonly referred to as SG-2000[34]) introduced and demonstrated a teff thresher in 2012 at the farming training centre of the Yilmana Densa *Woreda*. But it only threshed 9 QT of teff before breaking down. It is now abandoned at the site. The machine was fabricated in Ethiopia and four youth were trained to use the technology. The farmers commented that the teff thresher did not separate the grain and the straw. Specifically, the thresher broke down the straw into small parts. The straw is the major feed for livestock.

In a separate case, the Abollo threshing machine was introduced by Mamaya for commercial farmers, research institutes and unions in the Northwestern Ethiopia. The machine is an Abollo Thresher with Screw, made by Abollo in Turkey. One importer, Woreta International Business Group PLC, quoted our researchers a price of USD 20,000, also noting that availability of the equipment was usually only upon advance order. (Abollo is sold by other distributors in Ethiopia as well, indicating its brand recognition in the country.)

This price excluded the cost of a tractor, which would be necessary for pulling and powering the machine. The marketing website[35] indicates that the thresher works for "wheat, barley, rye, oats and other cereal varieties, with additional belt-pulley system and sieve variants chickpeas, beans, lentils, sorghum and similar plants can be blended by this machine." We confirmed with the vendor in Turkey that the machine would also be able to handle maize and soybeans. The vendor stated that the TYD-01 model has a capacity of 1.35-1.70 MT per hour.

The types of equipment available seem to be more upstream (thresher, winnower or combined), rather for downstream operations (for example, drying equipment of any kind). Threshers seem to have been designed for one specific crop (for example, say wheat) and may have been used for other crops (barley, soybeans, teff, and maize). Operating parameters and conditions for other crops (most likely different than for original intended crop) may not result in optimal performance by the equipment. This seems to be the reason for the

[34] "Ethiopia." SAA SAFE, 2023, https://www.saa-safe.org/www/ethiopia.html.

[35] "Thresher with Screw." Abollo Agricultural Machinery, https://www.abollo.com.tr/p/products/harvester-machines/thresher-with-screw.html.

observation ‘The threshing machine did not clean the teff seed from straw and chaffs, it simply threshed and provided uncleaned seed and thus, forcing farmers to winnow and clean the seed from chaffs. This was not an issue for wheat.’ Looking at some pictures provided, the non-performance (or lack) of the blower may have resulted in pieces of stalks in grain streams. Also, the teff thresher ‘broke down the straw into small parts’; this indicates either 1) the crop is too dry/ brittle for threshing, or 2) blower is slow not blowing off chaff, or 3) the openings on sieves may be too big for them to fall pass through with grains[36]. Also, the threshing drum could be running too fast providing very little residence time.

A multi-crop thresher (MCT), which can be utilized for a few other grain crops that need threshing by adjusting key parts/components and operating conditions. Beans (soybeans, dry beans, and pulses) could easily be threshed with proper adjustments in sieve sizes and blower revolution speed. Sorghum and minor millet are two other grain crops that need threshing and MCTs should be able to handle them as well with proper adjustments.

The Abollo vendor says their equipment can handle chickpeas, beans, lentils, sorghum along with wheat, barley, rye, oats and other cereal varieties[37]. However, this equipment generally seems to be bigger in size (output and build), requiring a tractor for transportation, and higher fuel consumption. While this size could be better fit for co-op level operation, farmer-entrepreneurs would benefit from a scaled-down version of similar equipment.

2.6. Identified models in Ethiopia

Although we encountered various threshers, we were not able to identify many of the models that had been produced locally. However, two imported threshers appear to have most control over the market:

Model	Price	Location	Technical
Soilmaster Multicrop Thresher	ETB 725,000 (USD 14,500) Cash Only	Bahir Dar	1.2-1.5 MT/hour Electricity (220v)
Abollo TYD-01 (sold by *Woreda* International)	ETB 1,100,000 (USD 20,000)	Addis Ababa, Bahir Dar	1.35-1.70 MT per hour Tractor power (35 hp)

Figure 5: Images of the Abollo thresher in operation in Ethiopia

36 It is unclear if this has a sieve screen, which is a technical consideration for future research during pilot.
37 "Thresher with Screw." Abollo Agricultural Machinery, https://www.abollo.com.tr/p/products/harvester-machines/thresher-with-screw.html.

2.7. Equipment manufacturers and suppliers in Ethiopia

We identified equipment manufacturers and suppliers in various locations; however, most were located in Addis Abab and Bahir Dar.

Organization Name	Location
Amhara Metal, Machine, Industry Technology Enterprise https://amharametal.com/ Regional government-run enterprise manufacturing local equipment.	Bahir Dar
Mamaye Plc (supplier)	Bahir Dar, Addis Ababa
Ambassel Trading http://www.ethiomarket.com/ambasel/ Large importer/exporting company covering multiple industrial and agricultural technologies and inputs such as chemical fertilizers, agro chemicals, agricultural machineries and implements, building materials, tires and tubes, spare parts, earth moving machineries, and industrial raw materials.	Bahir Dar
Woreta International Business Group PLC https://weretaib.com/ Larger importer, exporter, and manufacturer including distribution/sales of CASE tractors. Also sells Abollo multicrop threshers	Bahir Dar, Addis Ababa
Kaleab PLC https://www.kaleabtrading.com/ Importer/exporter of raw materials and processed goods. Some indication of dealing in machinery (and most especially spare parts) from its website.	Addis Ababa
Agricultural Development	Addis Ababa
Mandela Temsgen Supplies thresher; cleaner small machine. Abollo, Agri-mer, Soilmaster. All are imported from Turkey and Brazil.	Metema, Gendewuha
Alt Agricultural Equipment Importer Plc https://www.facebook.com/Alt-Agricultural-Equipment-Importer-Plc-1430349883921964/ Sells Abollo multicrop threshers	Addis Ababa

2.8. Milling services

Milling services are much more prevalent across Ethiopia, perhaps because (1) they more easily process multiple types of crops (interviewees stated, for example that a single machine can handle wheat, teff, chickpea, fava bean and lentil without issue), (2) they generally can be positioned in a more stationary location such as near a town and market, (3) they are generally cheaper than postharvest equipment, (4) they are easier to run and maintain, (5) the machines operate nearly year-round and are not as seasonally dependent like threshers, and (6) they add value further up the value chain where the unit economics are more viable (e.g., the market price per kg is greater for powder than for pre-processed crops and therefore the gross profit is greater).

Even then, milling service provider charges vary by location. For example, in the Godino *Kebele* (in the *woreda* of Ada'a[38]) service providers charged 2-3 birr per kg. In nearby Akaku *Kebele* (about 15-20 km away), service providers charged ETB 2.0-2.50 per kg.

According to interviews with milling service providers, lentil milling is much simpler than fava milling because of its small size. But crop type is only one variable. Throughput also varied based on the age of the

[38] "Ada'a District." Wikipedia, 2023, https://en.wikipedia.org/wiki/Ada%27a. 23-30. For reference, this is close to the Godino and Akakau Kebeles–about 15-20km distance.

machines, frequency of maintenance, and availability of electricity. Milling machine operators stated throughput can vary between 1.5-3.0 QT per hour based solely on the age of the machine.

Their customers, they said, were a community (farmers, neighbors, and town people) living in their area and adjacent *kebeles*. There were competitive owners of the machine in the area, but they said customers preferred their services based on the quality of the processing

Figure 6: Multipurpose crop millers at Godino and Akako *Kebeles* of Ada'a *woreda*

Section 3: Evaluating Opportunities to Increase Postharvest Mechanization for Smallholder Farmers

3.1. Finding the variables for success

Any solutions to improving postharvest processing in order to improve the lives of smallholder farmers therefore require the users—smallholders, entrepreneurs, and downstream customers—to be at the center of the design or innovation.

We approached this using the core principles of human-centered design, a problem-solving technique that puts people at the center of the development process, enabling products and services to be created that resonate and are tailored to their needs[39].

Throughout the research, we took into consideration the core elements of human-centered design that lead to successful adoption of any design or innovation. We used the lenses of desirability (*do people want it?*), feasibility (*is it technically and logistically possible to do it?*), and viability (*does it make financial sense?*) to evaluate farmer and service provider needs and perspectives in the postharvest processing space and assessing the potential options across the range of crops evaluated.

These are very similar to the 4As (availability, accessibility, affordability, and awareness), which are also commonly used when evaluating elements of successful solution design[40].

Figure 7: Lenses for design consideration

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[39] Landry, L. "What Is Human-Centered Design?" Harvard Business School Online Blog, Harvard Business School Online, 2023, https://online.hbs.edu/blog/post/what-is-human-centered-design.

[40] Sheth, J., & Sisodia, R. (2011). The 4 A's of Marketing: Creating Value for Customer, Company and Society (1st ed.). Routledge. https://doi.org/10.4324/9780203802168

3.2. Key design considerations

Using these human-centered design principles, we identified 8 key design considerations.

1. **Equipment owners are likely local entrepreneurs.** Smallholder farmers simply cannot afford technologies with a price range of $700-5,000. Therefore, the only way to spread the cost among farmers is to have them pay for a service provider. This service provider is likely to be a local entrepreneurial individual or cooperative.

   Although medium and large-scale farmers are more capable of buying machines and are potentially interested in sharing spare capacity, their priorities will always be first to their farms, which inhibits the service provider model. That said, they are often the type of entrepreneurs willing to set up the businesses and offer the services to smallholders, which we saw in the existing models in Ethiopia where these businessmen purchased the equipment and offered a lease-to-buy model to youth.

   Additional potential ownership models, such as group cooperatives, were also considered. We are more open to cooperative structures for large, shared spaces, such as storage. However, for a business model such as threshing that requires only 1-2 pieces of equipment and 1-2 operators the potential issues—shared ownership, governance, and accountability—seemed overly complex.

2. **Portability is essential.** For most crops, postharvest services need to be located near farms. The volume of unprocessed crops makes it difficult to transport the gross volume to a faraway service provider, such as someone situated at a market. For farmers to take up any service provision, they need it to be within easy reach. This means that the service provider needs to go to the source of the product, such as the household or farm. To make this possible, a motorbike or tricycle is required to carry or pull the equipment to the location.

   A tricycle cargo carrier

   Photo credit: Dasiba Tamale

   Potential transport solutions vary. The biggest machines will need to be pulled by tractors, which are expensive. Small equipment can be held or strapped to a motorbike, but this can pose safety risks to both driver and machine. A machine that falls off the motorbike because it is poorly secured is a potentially useless machine. The middle ground is likely a transport solution that can safely hold the equipment, navigate mediocre terrain, and still be not as expensive as a tractor. Three and four-wheeled cargo carriers, particularly the tricycle version common in many sub-Saharan African countries, are therefore the likely solution.

3. **Limited access to electricity means gas/diesel machines work best**. Among the more than 110 million people living in Ethiopia, only 46% use electric energy for day-to-day activities like food preparation and other tasks. In rural areas of the country where 80% of the population lives, people have no sustainable energy supply[41]. Unfortunately, Ethiopia has faced fuel shortages in the past, which has also led people to seek to avoid dependence on it as well[42]. Photovoltaic (PV) solar panels may appear to be ideal solutions where electrical grid infrastructure is limited and shortages of fuel are a risk (in addition to their lower environmental footprint); however, PV solar panels are not capable of powering some of the larger machines on their own, and batteries to store the energy are prohibitively expensive. Therefore, gas and/or diesel motors are likely best options for power, even if service providers adjust their pricing to clients based on the type of power. For example, teff

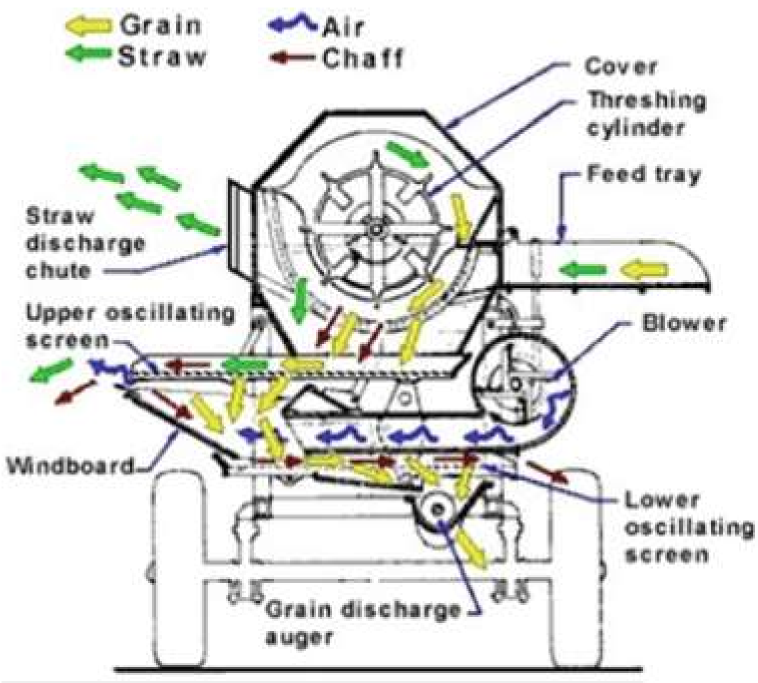
[41] Getie, Elias Mandefro et al. "Poverty of Energy and Its Impact on Living Standards in Ethiopia." Journal of Electrical and Computer Engineering, vol. 2020, Hindawi Publishing Corporation, 2020, https://downloads.hindawi.com/journals/jece/2020/7502583.pdf.

[42] Tadesse, Fasika. "Drivers Wait Eight Hours to Refill in Ethiopia Amid Fuel Crisis." Bloomberg, 5 July 2022, https://www.bloomberg.com/news/articles/2022-07-05/drivers-wait-eight-hours-to-refill-in-ethiopia-amid-fuel-crisis.

farmers are charged ETB 2.00/kg when using an electric milling machine while milling with a diesel engine is ETB 2.50/kg.

4. **Technical design is likely to be one of the biggest contributors to success.** It seems easy to buy (or build) a machine for postharvest processing, whether it be threshing, drying, or slaughtering and expect that it will just work optimally. However, the design, selection, setup, modification, and maintenance of technologies to fit the specifics needs of the service may make or break the microbusiness's success. For example, we heard in interviews with users of a teff thresher that it "broke down the straw into small parts", which was not ideal. This indicates either the crop is too dry/ brittle for threshing, blower is slow not blowing off chaff, or the openings on sieves may be too big for them to fall pass through with grains. Only knowledgeable technicians can diagnose and fix this issue, and oftentimes once the equipment has been purchased it is too late to fix. Our goal is to find equipment that is efficient, easy-to-maintain, and manageable.

Figure 8: Diagram illustrating the basic operation of a thresher[43]



5. **Financing is essential.** Data on savings rates of citizens and businesses in Ethiopia, especially rural Ethiopia, is limited[44], but it is unlikely that entrepreneurs in rural locations will be able to afford the upfront costs of establishing postharvest service businesses, which can range between USD 700 and 5,000. Without access to supporting financing mechanisms, such as loans or leases, entrepreneurs seeking to start a postharvest processing business will be unable to do so. In addition, interest rates and the terms of the loan can make or break the business. Ethiopia's rates are relatively modest at 13-18% (lower if borrowing in dollars, pounds, or euros)[45], but many of these services are seasonal, while traditional loan repayment structures are monthly. This needs to be recognized and managed.

6. **Ownership creates sustainability.** Despite the financing hurdles, simply giving the equipment away or overly subsidizing the program may lead to lack of long-term sustainability, as owners may

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[43] Mahmood, Yasir, et al. "Design Modification for Anti-choking Mechanism in Thresher Machine: Proceedings of iNaCoMM 2017." Machines, Mechanism and Robotics, 2019, pp. 585-593.

[44] "Determinants of Rural Household Savings in Ethiopia: The Case of East Hararghe Zone, Oromia Regional State." Journal of Economics and Sustainable Development, vol. 4, no. 9, 2013, pp. 12-23. IISTE. https://www.iiste.org/Journals/index.php/JEDS/article/download/4329/4397

[45] "Best Bank Loan Interest Rate in Ethiopia 2022." Banksethiopia.com. https://banksethiopia.com/best-bank-loan-interest-rate-in-ethiopia-2022/

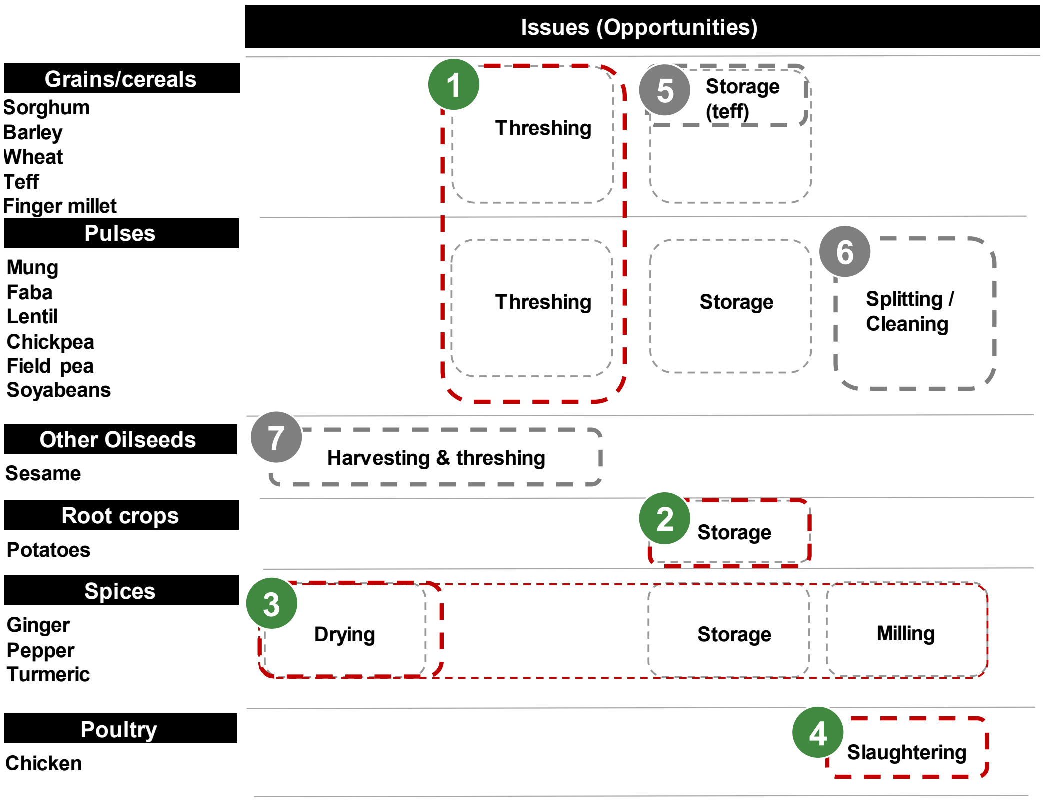
not have sufficient 'skin in the game' to carry forward the businesses. The goal should be to avoid models that do not create a full feeling of ownership and to avoid having machines be abandoned once broken.

7. **Nuance in each business model means that testing and piloting is essential.** No matter how much research, interviewing, and forecasting we do, only the real world can prove to use if something will work. Nuance should not be overlooked. An obvious example would be the selection of crops for MCTs: it takes some MCTs 22x longer to process soybeans than it does maize. Although service providers charge more for crops that process more slowly through machines, the pricing is not in proportion. Farmers are simply not willing to pay 22x the price, and soybeans are rarely worth 22x more in market value. As a result, service providers are likely to always prioritize maize over soybeans when they have the choice. There are many more subtle, nuanced examples that are likely to become much more obvious once the models are tested in the field.

8. **Basic postharvest service provision is an entry point for additional agricultural services.** Enabling an entrepreneur to operate service provision for basic crops such as teff and soybean threshing may open doors to additional services in the future, such as hermetically sealed bags sales and input and fertilizer services. While this analysis focuses on postharvest processing, shared mechanization of land preparation, harvesting, and value add processing are also possible; however, because the capital cost of such machines is generally higher, their adoption may happen later, once farmers see the value of postharvest processing equipment.

3.3. Opportunities identified

Our research identified numerous potential opportunities across the crops, their value chains, and regionally. We identified these opportunities by looking at the biggest issues and evaluating whether solutions might be clustered. Following this, we identified seven areas to explore further and narrowed it down to four specific opportunities for detailed analysis.



3.4. Opportunities prioritized for detailed analysis

Opportunity 1: Grains/cereals/pulses threshing

Most of these crops are grown in the same regions. Farmers frequently grow multiple crops. There is potential ability for MCT technology to bring mechanized threshing to these areas. The opportunity looks especially promising because in some areas there was demonstrated evidence of such technologies and business models already succeeding. The biggest hurdle to scaling up is likely the high up-front capital requirement.

Opportunity 2: Potato storage (seed and ware)

With estimated postharvest losses of around 50%, there is a big need for improved storage capabilities. Most farmers today store their potatoes in their homes on the floor. Storage solutions that are relatively low-cost but may not be prioritized by farmers compared to other costs such as farm inputs.

Opportunity 3: Spices drying (ginger and chilies)

There are similar drying needs for all spices, particularly because the spices are currently either sold wet or are dried in open air under the sun, which exposes them to dust and other matter that degrades quality. Poor drying also likely leads to persistent aflatoxin issues, especially in chilies[46]. Although drying solutions are relatively low-cost compared to the capital costs for other crop postharvest solutions, the volumes must be big enough to justify implementation. In addition, there is relatively high up-front expenditure required (>USD 500) that creates a barrier to implementation. Storage (plastic bags) and milling are potential add-on businesses.

Opportunity 4: Poultry slaughtering

At first glance, the per capita consumption of poultry in Ethiopia appears to mean this is too small of a market, the demand for properly handled poultry meat by catering companies, hotels, and restaurants is very high. Existing poultry farmers have little access to modern slaughtering facilities, leading to biohazard/contamination during processing. The gap in the market requires these buyers to import poultry meat instead.

3.5. Opportunities that were deprioritized

Opportunity 5: Teff storage

While most crops can harness improved low-cost solutions such as hermetically sealed bags (e.g., PICS); teff does not appear to meet the criteria for such bags because of its small grain size and its interaction with moisture. Postharvest losses during teff storage are only 2.2-3.3%[47]. The low rate of post-harvest loss for teff is due to its small size which makes it resistant to insect attacks[48]. We therefore deprioritized this from our opportunities list.

Opportunity 6: Pulses splitting and cleaning

Splitting and cleaning pulses includes the process of winnowing (removing the chaff and other debris from the pulse seeds) and dehulling and splitting. Some winnowing and even dehulling is covered by use of reliable mechanized threshing, while other aspects are further down the value chain. We recognize the need for splitting and cleaning; however, we decided to stay focused earlier in the value chain where we thought the solutions could have a bigger impact.

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[46] Tolera, Tariku Hunduma, Antenen Tesfaye, and Melaku Alemu. "Aflatoxin Contamination of Ethiopian Hot Red Pepper and Risk Characterization: Dietary Exposure Assessment and Estimated Aflatoxin-Induced Hepatocellular Carcinoma." Ethiop. J. Agric. Sci., vol. 30, no. 4, 2020, pp. 63-81. https://www.ajol.info/index.php/ejas/article/view/201120/189642.

[47] "Post-Harvest Losses in Ethiopian Teff." Africa South of the Sahara, 16 Nov. 2016, https://ssa.foodsecurityportal.org/blog/post-harvest-losses-ethiopian-teff.

[48] "Managing Post Harvest Loss Another Means to Ensure Food Security." Ethiopian Business Review, https://ethiopianbusinessreview.net/managing-post-harvest-loss-another-means-to-ensure-food-security/.

Opportunity 7: Sesame harvesting and threshing

Sesame is unique in that harvesting is very difficult, but threshing is relatively straightforward. As this analysis was focused on postharvest opportunities, we deprioritized the sesame opportunity.

Section 4: Business Profiles and Technologies

Taking into account the research findings and key design criteria, we conducted a more detailed evaluation of the four prioritized opportunities:

1. Grains/cereals/pulses threshing
2. Potato storage
3. Spice drying (& storage and milling)
4. Poultry slaughtering

For each of the models, we evaluated the potential viability, feasibility and desirability to determine a setup and structure most like to succeed. This required evaluating the likely market size and volumes, revenue, operating costs, and financing costs based on a number of static assumptions applied to some more open-ended business model structures.

4.1. Market size

The size of potential revenue is a key aspect of the viability of the business. To understand the market size for a postharvest processing business, we consider the geographic area in which any such service provider would operate, which we call a catchment area[49].

While confident in the overall market size—known as the "addressable market"—for a given catchment area in a region by type of crop, we were less certain about the uptake of services—known as the "obtainable market"—by customers (farmers). As a result, we reiterate that the obtainable market is an estimate that must be tested and validated in a pilot.

Both addressable and obtainable market size depends on the business profile. Service providers that are stationed in market towns, for example, may have a large number of villages within the catchment area, increasing the addressable market size. However, due to the dependence on transport of the raw materials to the service provider's location, the number of customers within each of the villages will likely be lower.

The same is true for service providers who travel to multiple villages or directly to farms. Although the addressable market is higher, and the willingness to pay of customers may be relatively high, the ability to obtain customers may be impacted by 'logistical complexity', such as waiting for customers and downtime for travelling. We consider this in the obtainable market estimates.

Figure 9: A view of how to evaluate market sizing

Addressable Market. Using a basic catchment area based on the size of the *woreda*, we calculated the estimated annual production volumes for our target crops within a catchment area, by select *woredas*. We chose proxy *woredas* (1) where we thought it would provide a realistic assessment of the type of business to operate in that area using the technologies proposed, and (2) where we were able to obtain *woreda*-level

[49] "Catchment Area." Wikipedia, Wikimedia Foundation, 7 July 2023, https://en.wikipedia.org/wiki/Catchment_area.

production information. This data was usually sourced from local government offices. We took significant reductions in the estimated volumes based on the geographic dispersity of the *woreda*, or—if portability was part of the business model--increased the volumes if the *woreda* was geographically small and therefore likely for a business owner to cover multiple *woredas*. This was not scientific, but instead was intended to give a rough estimate of a more realistic size of the addressable market.

Obtainable Market. We estimated obtainable market of a catchment area based on our own validation surveys with potential customers, the uptake of customers by existing service providers who serve as useful proxies, and by comparing these estimates with other programs we have seen with previous research.

Although the obtainable market is likely to grow over time as farmers become more aware and accepting of new businesses in the area, we maintained a static percentage over the life of the forecast. While there is anecdotal evidence from our interviews that these business models are mostly 'early adopters', they are (intentionally) not completely 'innovative', and so do not deserve more optimistic increases in obtainable market that one sees in the technology adoption lifecycle[50].

In most cases, the limitation was not the size of the market, but the throughout or capacity of the technology. For example, MCTs can only thresh a certain amount of crops per hour, and operate only a certain amount of hours per day. Most of our effort to find the obtainable market was based on not exceeding capacity, a positive sign that the market size was large enough to support these businesses (at least in some areas).

Figure 10: Innovation Adoption Lifecycle

The uptake curve of new technologies by users can serve as a guide of obtainable market in early stages of the venture.

Image Credit: Wikimedia Foundation

4.2. Other key assumptions

Pricing. We were generally able to determine pricing for the services by using examples from existing businesses in Ethiopia. For example, it is generally accepted that teff threshing services are priced at ETB 400 per QT (ETB 4000 per MT). Other crops, such as finger millet did not have threshing prices, so we used crops of similar market price and physical structure as a proxy. For some business models, such as potato storage and chili drying, pricing strategy became a key driver in the evaluation of the likely success of business models not yet adopted. In those cases, we provided a range of pricing to understand the likelihood of viability and highlighted this "willingness to pay" question as an important point for the proposed pilot.

Operating Costs. Each business opportunity we designed and analyzed included base assumptions around operating costs, which included items such as labor, security, fuel, and maintenance. These assumptions were determined from the research or provided by the RAISE-FS team members working on the ground.

Capital Costs. We created high-level estimates of the up-front capital costs using information available from suppliers or Bountifield's all-in costs working in Kenya. In most cases we rounded up significantly to account for unforeseen costs. Ethiopia does not charge import duties on agricultural machinery[51], so we did not add any of these costs for threshers, tractors, etc., but we did consider the potential duty at a high-level for portability equipment such as motorbikes.

Financing for Capital Costs. An important element is the financing of the up-front costs. We assumed asset financing of 3-10 years depending on the equipment, repaid monthly with an interest rate of 15%. A 10% downpayment by the borrower was included. We are aware that such an up-front percentage could be prohibitive for most borrowers; however, we think it is realistic expectation by the lenders and that

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[50] "Technology Adoption Life Cycle." Wikipedia, Wikimedia Foundation, 7 July 2023, https://en.wikipedia.org/wiki/Technology_adoption_life_cycle.

[51] "Ethiopia Ministry Waives Duties on Agricultural Machinery." AGRA, 2023, https://agra.org/news/ethiopia-ministry-waives-duties-on-agricultural-machinery/.

entrepreneurs fronting cash are more likely to have 'skin in the game' to carry forward with the business, even when times get tough. That said, the developer of a program pilot could test alternative models that work around this up-front financing, such as grants or third-party equity investment.

Secondary Revenues. Many of these businesses hold a large potential for additional revenue outside the core business, particularly because agriculture is so seasonal. For example, an entrepreneur with a threshing machine that is transported with a cargo bike is likely to earn revenue from the cargo bike in the offseason. We did not include these potential secondary revenues in the analysis.

4.3. Opportunity #1: Grains/cereals/pulses threshing

The first business model we identified is the threshing of grains, cereals, and pulses using a multi-crop thresher (MCT), performed by the services of a local entrepreneur for farmers. The threshing service must be able to come to the location of the farmers due to the volume of the crops.

This model is already evidenced and proven in some areas of Ethiopia, mainly operated using large-scale Abollo MCTs pulled by tractors. In some cases, the machines are operated by youth and financed by local wealthy businessmen.

MCTs are appealing because of their wide-ranging applicability to crops, including maize, teff, soybeans, sorghum, pigeon peas, cowpea, millet, mung beans, and even paddy rice.

We selected two MCT technologies that are likely to suit this model. We took into consideration several important variables, including throughput capacity, number of operators required, portability requirements, and overall cost. Although the MCTs identified are not yet available in Ethiopia, they were selected because they met the criteria of relative low cost, likely applicability to the target crops, and portability. Bountifield has already these two MCT models in Kenya on some of the in-scope crops.

Figure 11: Proposed thresher technology options, including costs and potential compatibility with crops.

	PROPOSED BIT-10 (with double blower)	PROPOSED SL-3-2 (orange)	TYD-01
Equipment Price	US $950	US $950	US $20,500
Power Source	Separate Diesel Engine (US $285)	Separate Diesel Engine (US $285)	Tractor (US $10,000+)
Weight	60 kg	60 kg	1,650 kg
Crops Likely Likely, with modification Unknown Unlikely	Sorghum (0.8 MT/hr) Barley Wheat Teff Finger millet (1.0 MT/hr) Soya Mung (1.2 MT/hr) Faba Lentil Chickpea Field pea	Sorghum (0.8 MT/hr) Barley Wheat Teff Finger millet (1.0 MT/hr) Soya Mung (1.2 MT/hr) Faba Lentil Chickpea Field pea	Sorghum Barley Wheat (1.7 MT/hr) Teff Finger millet Soya Mung Faba Lentil Chickpea Field pea
Transport	Motorcycle (US $5,000) or Tricycle (US $5,000)	Motorcycle (US $5,000) or Tricycle (US $5,000)	Tractor (US $10,000+)
Total CAPEX	US $7,000 ETB 350,000	US $7,000 ETB 350,000	US $30,500+ ETB 1,525,000+

Excluded because of commercial combine harvesting

We excluded wheat and maize from the scope of the financial analysis. Maize often works with MCTs but may not work well with the specific technologies we selected; wheat works very well, but our understanding is that wheat is a commercialized crop that is often harvested using mechanized combine harvesters that eliminate the need for small-scale threshing after harvest.

We also evaluated potential portability options that would work with the selection MCTs. Motorbikes are the standard default option, and these MCTs can be carried on motorbikes; however, there are safety limitations and our experience working in Kenya is that the MCT is likely to eventually fall off the motorbike, damaging—potentially permanently—the MCT. Therefore, we think alternatives such as a tricycle with a flatbed or a quadbike with a trailer is more likely to be successful. In some countries in sub-Saharan Africa, tricycles are becoming more prevalent and can be purchased at a cost not much greater than motorbikes. We were able to find some of these available for sale in Ethiopia, but they appear to be still not widely adopted. Quad Bikes and trailers are non-existent and likely need to be imported. For the purposes of this analysis, we did not assume one portable technology over the other, but instead used a general capex figure to calculate the financial viability. The specific portability option will need to be selected and tested during the pilot.

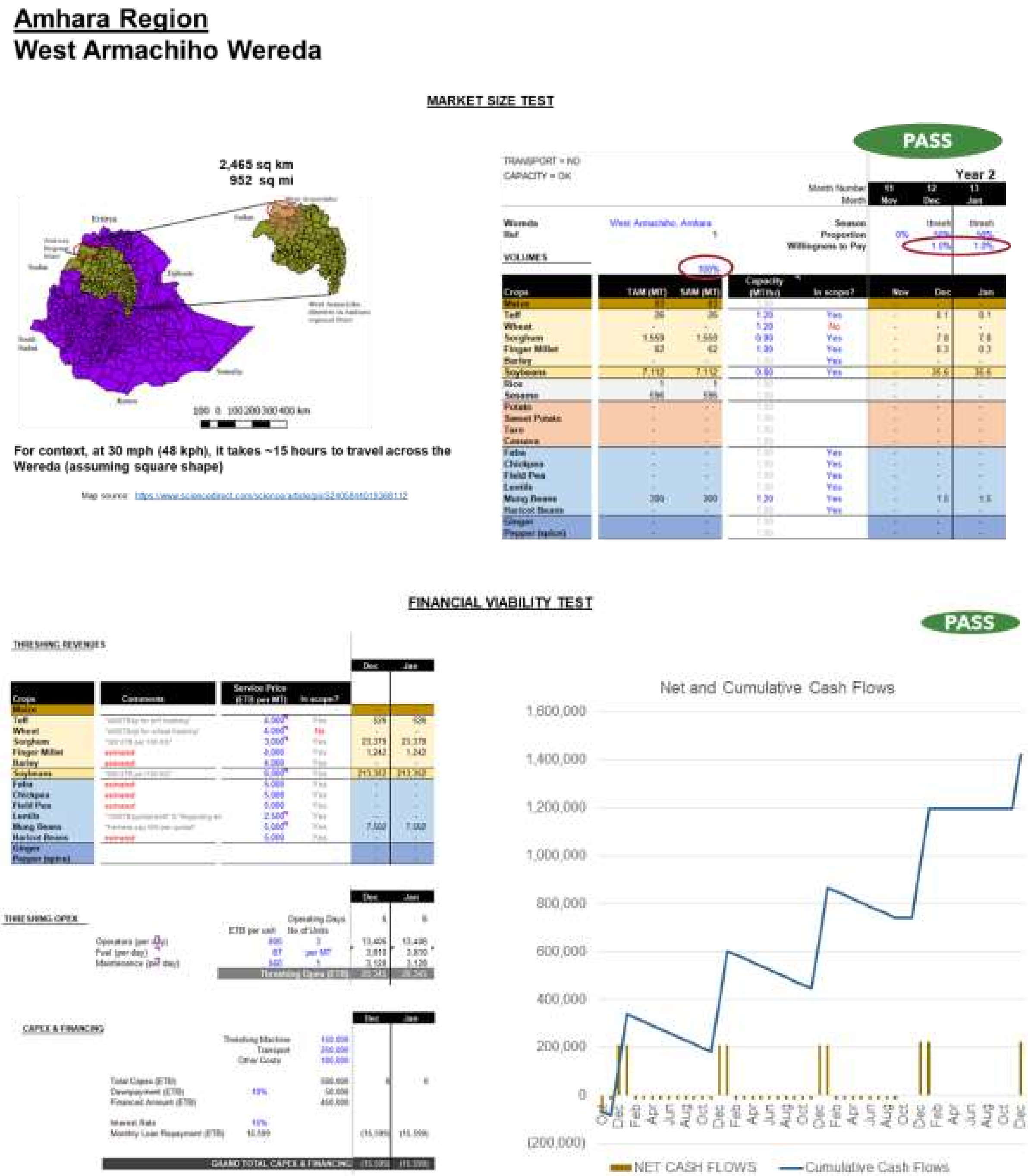
Figure 12: Potential portability options for MCTs

For the most part, the selected business models passed the test. For example, in the West Armachiho *Woreda* in the Amhara Region, an MCT could potentially capture 4% of the entire production in the area, but even if it only obtained 0.5% the business would still likely be financially viable. Other *woredas* similarly passed.

The ability to manufacture such machines within Ethiopia was considered, particularly because the suggested machines are sourced from China and not produced locally. However, for threshing, the equipment's technical specification is important, so local production might be more difficult. There are alternative MCT technologies that could be considered to hold potential for domestic production. For example, the Soybean Innovation Lab (SIL) has an "open source" threshing machine whose design can be used by any fabricator[52]. The potential issue is that its up-front cost is higher than the two models recommended, and its optimal function is for maize. If domestic manufacturing is a top priority for a program developer, then we suggest adding the SIL MCT to the pilot.

[52] nivensdesign. "The SIL Multi-Crop Thresher." SIL Activities & Impacts Report 2020. Issuu. https://issuu.com/nivensdesign/docs/sil_report_wkg_01-26-21_pages/s/11630122.

Figure 13: Example financial analysis of an MCT operator taking our financing in a sample woreda (West Armachiho)



Note: Cash flows do not include Owner distributions. It is important to consider that the Owner will likely require a minimum distribution for his/her own living costs.

4.4. Opportunity #2: Potato storage

The second business opportunity we identified was the storage of potatoes. Potato production has nearly tripled in the past decade, but high postharvest losses and observations during our field research of poor storage practices emphasized the importance of the potential for this crop.

There are two types of storage opportunities: eating (ware) potatoes and seed potatoes.

Eating potatoes are stored cool and humid so they do not dry out. This increases the chances of a little rot but keeps them from drying out and getting soft. Seed potatoes are stored cool and dry, so they do not rot at all[53]. These differing requirements therefore mean different solutions, and potentially different business models.

Before evaluating the business model options, it was important to first understand some important dynamics in the potato market and the likely "willingness to pay" of farmers.

First, there is clearly an upside for a farmer who can store his/her potatoes. During the harvest season, traders purchase from farmers for ETB 500 (USD 9.61) per 48kg sack. These prices can go as high as ETB 700 (USD 14.00) per sack in the offseason. This 40% difference means more potential income for a farmer, or even a big savings if the farmer is selling potatoes at harvest and buying potatoes for home consumption later in the season.

But there is an essential question that must be answered before recommending such a business model: will a farmer be willing able to sell their potatoes later in the season, or do they need cash urgently during harvest season? If they need the cash, no matter what business solution is presented it will not work. We were not able to comfortably evaluate this question. Even if a farmer said they had a willingness or ability to wait longer, the results in practice could be different. Therefore, this question is likely only answered in a pilot.

Second, we are aware of significant shortages of seed potatoes during planting season. Farmers are unable to buy seed potatoes during planting season and therefore must store (with high postharvest losses) their own potatoes. At first glance, the obvious solution would then be to give farmers a way to store their own seed potatoes. However, systemically, the right answer is not to use own seed, but to procure it from high-quality suppliers that can provide improved varieties that are more drought-resistant, disease-resistant, and that have greater yield[54]. In other words, introducing on-farm, local seed storage solutions could push out more systemic solutions that are better in the long run.

There are several initiatives and institutions in place to ensure a greater supply of quality potato seed in Ethiopia. One such effort is the promotion of decentralized seed potato production and quality assurance through a quality declared seed (QDS) scheme. A few seed potato cooperatives run by smallholders have started producing mini-tubers in screen houses to enhance early-generation seed (EGS) availability[55]. Additionally, ICCO's STARS program established a public-private partnership between farmers, a research institute, and a laboratory to address the issue of obtaining new and high-quality potato seed varieties[56]. Despite these initiatives, the system is not yet set up to distribute a consistent and quality supply, so there is probably a balance required between implementing a storage solution at farm level versus finding a systemic solution. Therefore, we evaluated two potential solutions:

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[53] "Seed Potatoes vs Regular Potatoes for Planting." Northern Homesteading, 11 Aug. 2022, https://northernhomesteading.com/index.php/2022/08/11/seed-potatoes-vs-regular-potatoes-for-planting/.

[54] "Isn't It Better for Farmers to Harvest and Reuse Their Own Seeds?" GMO Answers, https://gmoanswers.com/ask/isnt-it-better-farmers-harvest-and-reuse-their-own-seeds.

[55] "Systemic and Concerted Action Needed to Boost Seed Quality Assurance for Ethiopian Potato Sector." Integrated Seed Sector Development in Africa, 19 May 2021, https://issdafrica.org/2021/05/19/systemic-and-concerted-action-needed-to-boost-seed-quality-assurance-for-ethiopian-potato-sector/.

[56] "Improving the Potato Seed Production Chain for Smallholder Farmers in Ethiopia." ICCO Cooperation, https://www.icco-cooperation.org/en/news/improving-the-potato-seed-production-chain-for-smallholder-farmers-in-ethiopia/

Figure 14: Potato storage solutions

Seed Potato Storage

Advanced DLS storage using netting, managed by local seed producer cooperatives or businesses.

Estimated construction cost:
ETB 500,000 (USD 10,000)

Capacity:
400 Quintal (40 MT or 833 bags)

Ware Potato Storage

Near-farm eating potato storage using vented or charcoal storage, managed by a local entrepreneur.

Estimated construction cost:
ETB 50,000 (USD 1,000)

Capacity:
15 m³ = 50 Quintal (5 MT or 104 bags)

Seed Potato Storage

Seed potato storage needs to be handled centrally, and there are several cooperative structures already in existence in Ethiopia focused on seed production and storage. Creating additional cooperatives, supporting existing cooperatives[57], or supporting existing seed producer framers can be used to build medium-scale (40 MT) diffused light storage (DLS) structures.

Cooperatives or seed producer farmers can source high-quality seed from research institutions, paying around ETB 1,500 per QT early in the season, store those seed potatoes in the DLS warehouse, and re-sell the potatoes for ETB 3,000 per QT to farmers during planting season.

We calculated the potential financial viability for such a business using basic assumptions. The most important consideration for this type of business is the cash flow. There is a substantial up-front cost in purchasing the potato seed and then sorting it for months before resale. Even if highly profitable, the monthly expenses such as loan repayments, security and administration could make the business tenuous, particularly early on. Therefore, any such business likely needs a generous repayment holiday in the first year, and possibly a repayment structure that allows for balloon payments[58] when the revenues come in.

Figure 15: Calculating the potential financial viability of a seed potato business

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[57] Hirpa, Adane et al. "Analysis of Seed Potato Systems in Ethiopia." American Journal of Potato Research, vol. 87, 2010, pp. 537-552. SpringerLink, doi:10.1007/s12230-010-9164-1. https://link.springer.com/article/10.1007/s12230-010-9164-1

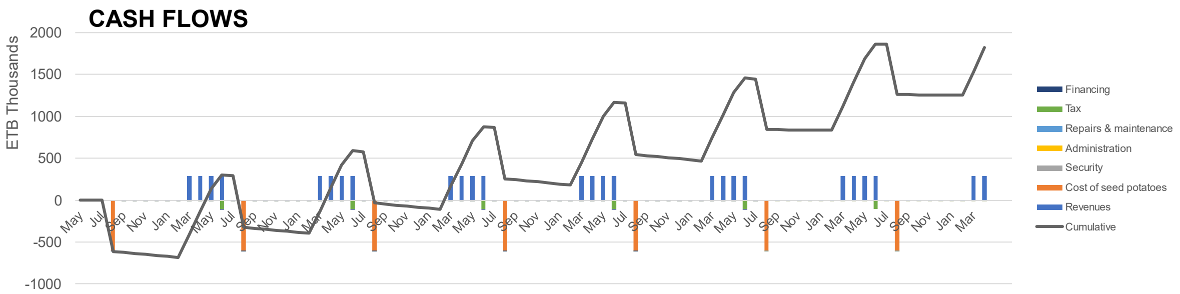
[58] A balloon payment is the final amount due on a loan that is structured as a series of small monthly payments followed by a single much larger sum at the end of the loan period. "Balloon Payment." Investopedia, Investopedia, 2023, https://www.investopedia.com/terms/b/balloon-payment.asp.

Assumptions		
Initial price paid for seed potatoes	1,500	ETB per QT
Price of seed potatoes charged to buyers	3,000	ETB per QT
Storage capacity	400	QT
Losses	5%	
Ending potatoes available for sale	380	QT

Financing		
Downpayment (ETB)	50,000	10%
Financed Amount (ETB)	450,000	
Loan Term (Years)	5	
Interest Rate	15%	
Annual Loan Repayment (ETB)	10,706	per month

Capex		
Upfront Cost	500,000	ETB
	$ 10,000	USD

Profit & Loss					
Revenues	**ETB**		**QT**		**Annual Total**
Sales of seed potatoes	3,000		380		1,140,000
Costs					
Cost of seed potatoes	1,500		400		600,000
Security	800	monthly wage	12	months	9,600
Administration	150	monthly cost	12	months	1,800
Repairs & Maintenance	600	monthly cost	12	months	7,200
				Less: Opex	**618,600**
				Pre-tax profit	521,400
				Less: Tax (20%)	104,280
					417,120



Note: Cash flows do not include Owner distributions. It is important to consider that the Owner will likely require a minimum distribution for his/her own living costs.

Eating (Ware) Potato Storage

Eating (ware) potatoes are stored in cool conditions with slightly higher moisture levels. Ethiopian potato farmers rely heavily on the crop for both their own diets and as a source of income.

If farmers are willing and able to wait to sell their potatoes until a later date when prices are higher, then they will need acceptable storage facilities that avoid the high ~50% postharvest losses that plague them today.

We evaluated storage at the household level and at local, shared level. We calculated that the estimated that a household would need a storage solution that costs no more than $200-400 (ideally less) to make such a solution financially viable, even before excluding any potential costs of financing.

Figure 16: Calculating the estimated value threshold for a farmer to pay for household storage

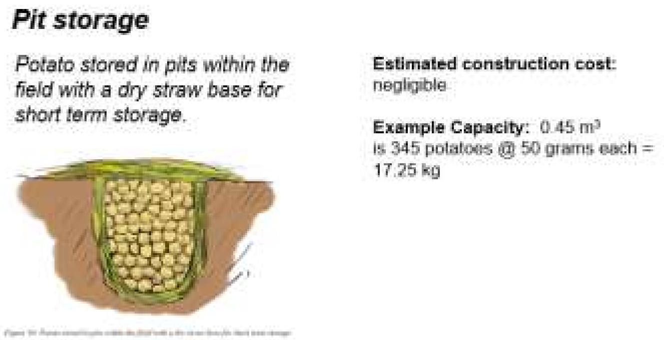
The average farmer in Ethiopia produces an average of 1.1 MT on 0.08 hectares of potatoes					
Household Size					
Potatoes to be stored	940	kg	0.85	% of all potatoes grown	
Losses using quality storage techniques	5%				
Farmer Benefit					
Value Low Season (per 48kg sack)	500	10.42	per kg		
Value High Season (per 48kg sack)	700	14.58	per kg		
	40%				

	Low	High
Farm size (kg produced)	**940**	**1,880**
ETB Value		
Value Low Season (per 48kg sack)	9,792	19,583
Value High Season (per 48kg sack)	13,708	27,417
Less: Losses	- 685	- 1,371
Benefit from storage (excluding costs of st(	3,231	6,463
	$ 65	$ 129
Value if spread over 3 seasons	$ 194	$ 388

(*Note: does not consider the cost of financing*)

USD 200-400 is not insurmountable, particularly if a few farmers were able to work together to pool resources. However, a cheaper and more practical option may just be to use pit storage if trying to solve the household-level problem.

Figure 17: Potato pit storage overview[59]

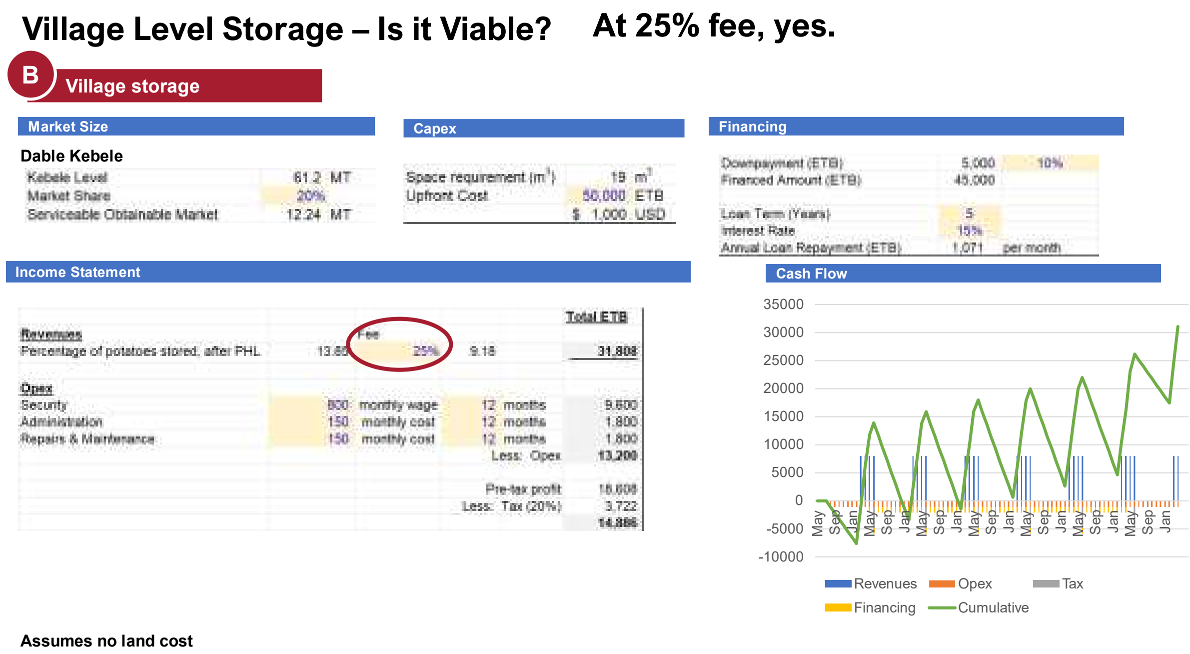


Alternatively, a service provider storage solution may result in lower losses and create more economic activity. We evaluated a model in which a service provider (or cooperative) offered the potatoes to be stored in a vented or charcoal storage unit. The service provider would earn their revenues by taking a percentage of the potatoes stored.

Using basic assumptions, we determined that such a model would be financially viable if the service provider charged a 25% fee, but not if it charged a 10% fee. In theory, both fees should be acceptable to the farmer, since the price increases 40%; however, this would need to be demonstrated in practice. Psychologically, is a farmer willing to pay 25%? Can the farmer even wait in the first place, or does he/she need to sell sooner? These are questions evaluated only in a pilot.

[59] Photo credit: Wasukira, Arthur et al. "Ware Potato Harvesting and Storage Techniques: Guidelines for Harvesting and Storage Management of Ware Potato." CGIAR Research Program on Roots, Tubers and Bananas (RTB), March 2017. https://cgspace.cgiar.org/bitstream/handle/10568/82788/RTB-Endure-Ware-Potato-Harvesting-and-storage-techniques.pdf?sequence=1&isAllowed=y

Figure18: Financial viability assessment of village level ware potato storage



Note: Cash flows do not include Owner distributions. It is important to consider that the Owner will likely require a minimum distribution for his/her own living costs. Land is assumed to be available without cost.

4.5. Opportunity #3: Spice drying (ginger and chilies)

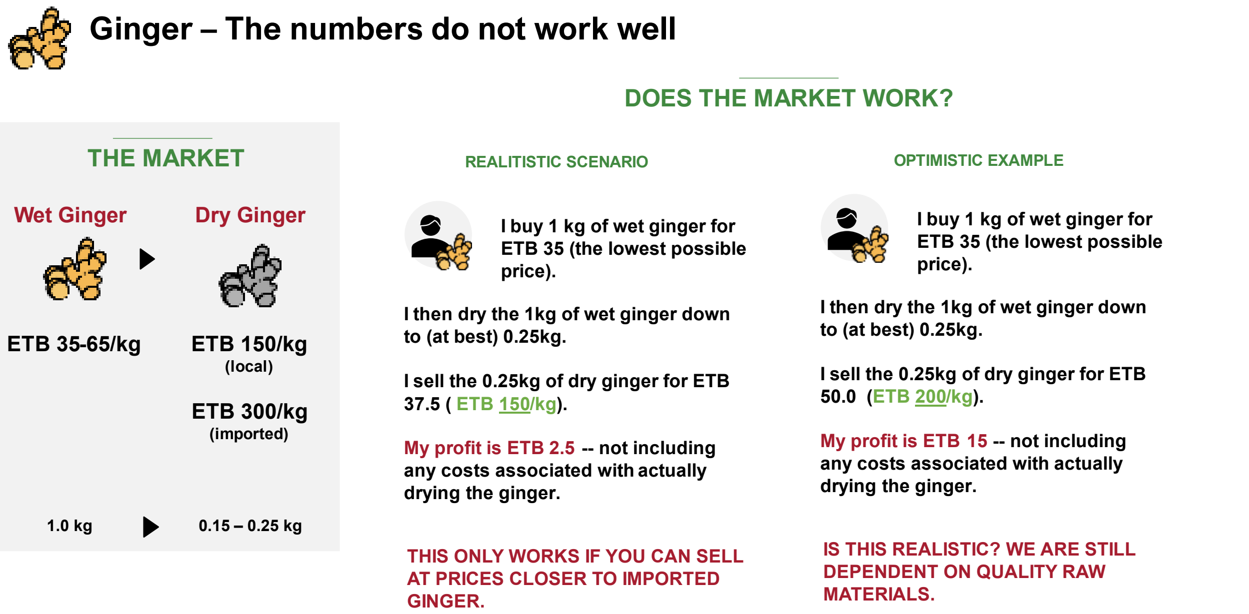
The third opportunity evaluated the potential for drying ginger and chilies (red pepper). These crops are grown in separate locations with the SNNP region and were therefore evaluated as separate business models.

Ginger

Most farmers sell their ginger 'wet' because they do not have drying capabilities and—more importantly—fear that their ginger will show symptoms of a diseased crop.

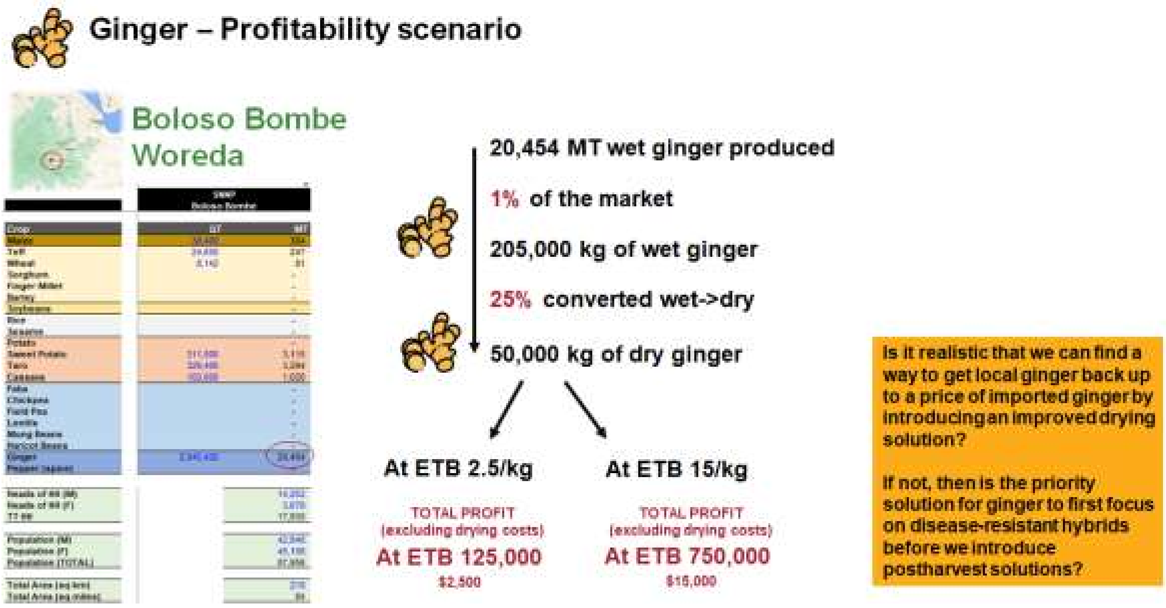
For multiple reasons, mostly a result of poor quality and disease-ridden ginger production, ginger is a buyers' market, and the price is set by traders. Even then, it does not seem profitable for hardly anyone.

Figure 19: A basic analysis of the profitability of ginger drying



The value of imported ginger is significantly higher (ETB 300/kg) than domestic ginger (ETB 150/kg). Therefore, if dried local ginger were to start trading closer to the imported price, this market would become more viable. But it is unlikely drying is the solution we should be focused on. Ginger production in Ethiopia has been plagued with disease and until quality raw materials that can resist disease are in place, investing in drying in hope of slightly improved pricing may be a futile exercise.

Figure 20: Potential profitability if drying local ginger would result in higher market price



Red Pepper Chilies

Unlike potatoes, chilies must be at least partially dried by farmers prior to sale. As a result of poor drying practices, the quality of the chilies is therefore immediately degraded. Aflatoxins, a persistent issue that is known to cause cancer, is exacerbated by poor drying[60].

Yet there is clear evidence that buyers are willing to pay more for quality. "Grade A" chilies can sell as high as ETB 200 on the market; but most is sold as "Grade B" for ETB 180/kg.

What if traders had access to more Grade A chilies? For this to be possible, drying must be improved.

We designed and evaluated a business model in which a service provider dried the chilies for the farmer in exchange for a percentage of the chilies dried. We found that just a 10% fee would likely be viable for the service provider, regardless of the technology. Assuming a farmer would be willing to pay 10% to potentially earn a higher market price, this business seems possible.

We researched two potential drying technologies, both of which are currently being employed in Bountifield's Kenya program.

The first is a Greenhouse-type warehouse that uses natural conventional currents where hot air rises and leaves the dryer through chimneys installed on the roof of the dryer while normal air comes through the dryer via ventilations on the side walls of the dryer. A large fan installed at the door improves drying capability.

The second is a photovoltaic (PV) powered dryer. It has a drying chamber where the air is heated. A fan pushes the hot air into the drying chamber where products have been placed on shelves to dry. This way the sun heat is not in direct contact with products.

[60] Fanta, Admasu, and Tesafa, Fentahun. " Aflatoxin related challenges and mitigation strategies of Ethiopia in spices, herbs and pulses' domestic and international markets." August 2018. https://www.researchgate.net/publication/337211699_Aflatoxin_related_challenges_and_mitigation_strategies_of_Ethiopia_in_spices_herbs_and_pulses%27_domestic_and_international_markets

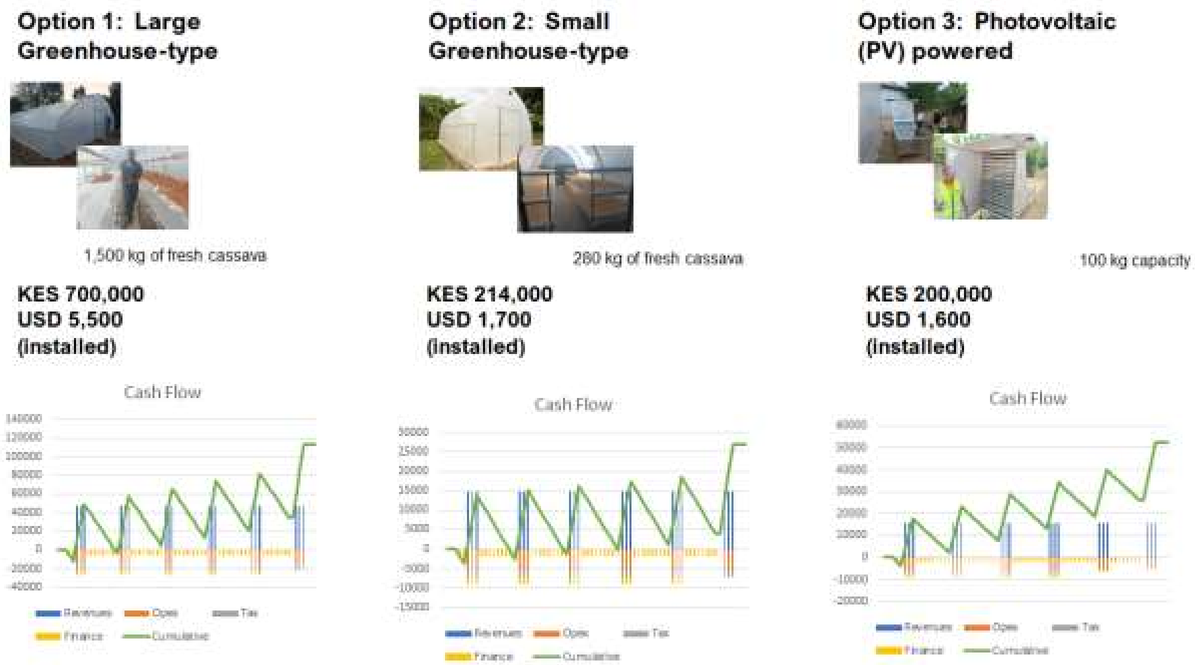
Figure 21: Potential chilies drying solutions[61]

We evaluated the financial viability of such systems, including splitting the greenhouse options into a small and larger warehouse. In all cases, on paper, the systems were financially viable, with theoretically potentially better profitability with the PV dryer. The true profitability will need to be tested. A PV powered dryer requires more maintenance and technical expertise, and its lifespan may be shorter than the 5-year financing we gave it.

That said, the financial analysis assumed the drying system was only for chilies and therefore used on a seasonal basis. However, such technologies could likely be employed for other crops produced in the local area.

It might also open the door to solutions in non-chilies areas. For example, ginger production is very high in Boloso Bombe, which also produces cassava, taro, and sweet potato – all potentially interesting for drying. The same could be said about potatoes in Oromia and Amhara.

Figure 22: Potential financial viability for three chilies drying solutions



[61] Photo credits: Bountifield International

Note: Cash flows do not include Owner distributions. It is important to consider that the Owner will likely require a minimum distribution for his/her own living costs. Land is assumed to be available without cost.

4.6. Opportunity #4: Poultry slaughtering

We evaluated the potential for poultry slaughtering through a well-managed facility. We selected the size of the facility after evaluating the potential supply vs. demand opportunity. The biggest demand opportunity is with hotels, restaurants, catering companies, and retail shops such as supermarkets and animal products retailers, who cannot risk buying meat from poorly run slaughterhouses, and therefore import their meat instead. The supply of chickens is the bigger issue. Small-scale and medium-scale farms do exist and lack access to slaughtering facilities, but they must be located close enough to a slaughterhouse to make the setup logistically efficient.

Using Bishoftu (located in Oromia Region) as an example location, we estimated the potential availability of chickens for slaughter and from there determined that a small-scale facility processing up to 2 million chickens per year is ideal. In fact, a smaller facility is equally viable, but the setup costs do not seem to be substantially cheaper, so the facility likely needs to be prepared to be underutilized, at least in the early stages of the business setup. It is possible that chicken farms would establish themselves once they recognized there was access to slaughterhouse facilities, but this is an assumption that should be more thoroughly evaluated during a pilot.

Figure 23: Poultry slaughtering facility setup options (size and cost)

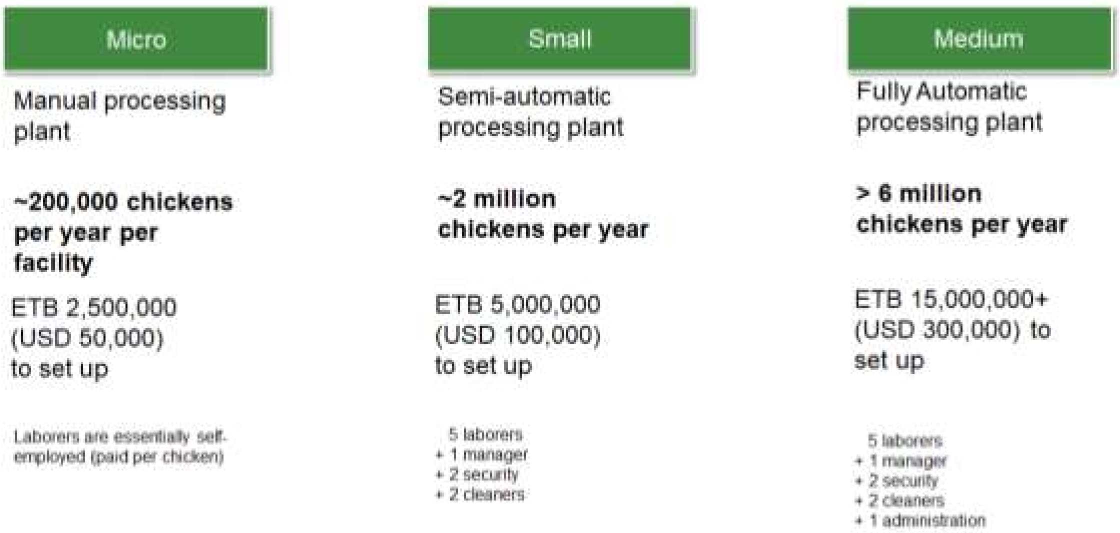
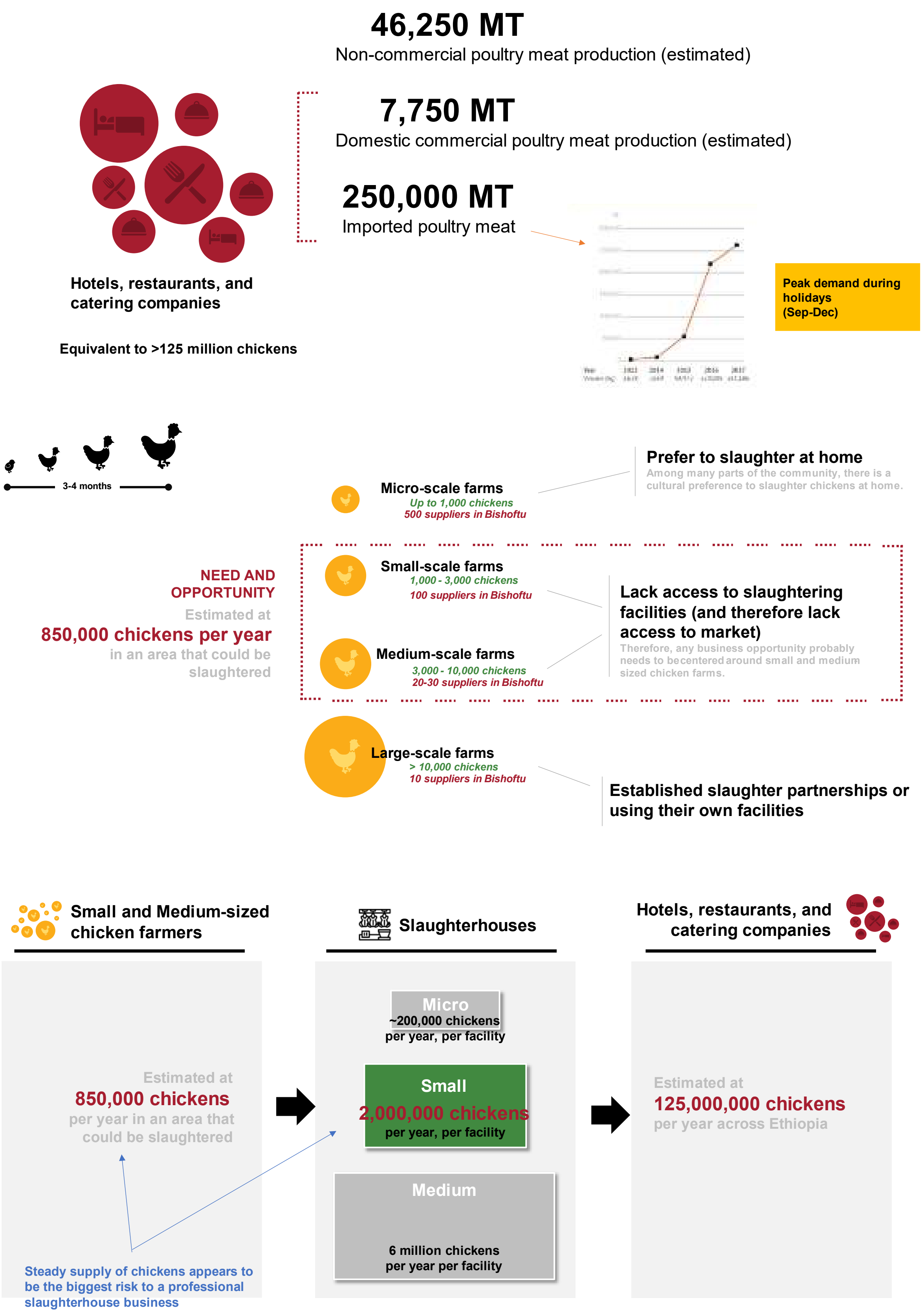
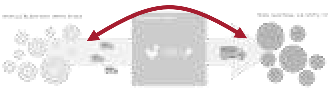


Figure 24: Evaluation of poultry demand and supply



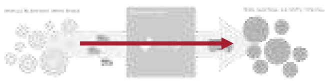
From there, we analyzed two potential business models, one in which the slaughterhouse charges a fee for the processing only (referred to as "toll processing" model) and the other in which the slaughterhouse buys the chickens, slaughters, and re-sells the meat ("trader" model). Both were financially viable, even when we estimated a significant decrease in market share in the trader model and a significant increase in sales and marketing costs. This is because the profit margins for poultry meat are significantly better than a low margin slaughtering fee.

Figure 25: Two business model options for poultry slaughtering



OPTION 1
Slaughtering facility is a toll processor

- ▶ Charges just for slaughtering service
- ▲ No marketing/sales to customers
- ▲ Not carrying inventory
- ▼ Logistically dependent on farmers and customers – 'perfect timing' leads to unmanaged downtime
- ▼ May still require refrigeration



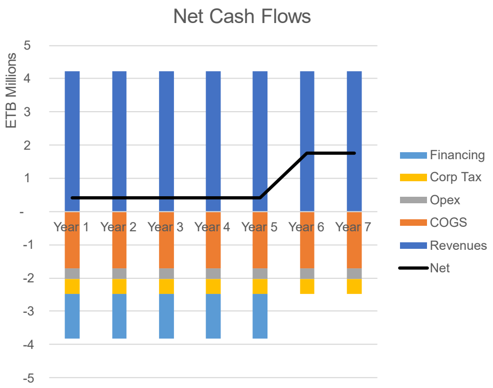
OPTION 2
Slaughtering facility is also a trader

- ▶ Buys chickens from farmers, sells meat to customers
- ▼ Requires Marketing/sales
- ▼ Requires refrigeration and inventory
- ▲ Increased margins from sales
- ▲ Optimized slaughtering schedule (managed downtime)

Figure 26: Profitability comparisons for poultry slaughtering

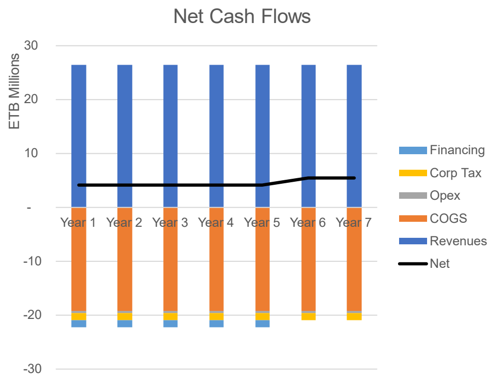
OPTION 1
Slaughtering facility is a toll processor

TAM chickens per year	2,137,500	
SAM chickens per year	887,500	
SOM chickens per year	177,500	20%
Operating days	22.19	
Operating months	1.01	



OPTION 2
Slaughtering facility is also a trader

TAM chickens per year	2,137,500	
SAM chickens per year	887,500	
SOM chickens per year	88,750	10%
Operating days	11.09	
Operating months	0.50	



Note: Cash flows do not include Owner distributions. It is important to consider that the Owner will likely require a minimum distribution for his/her own living costs. Land is assumed to be available without cost.

Section 5: Recommendations

We have identified four areas with Some or High likelihood of success and have prepared recommendations to take this forward.

Grains/cereals/ pulses threshing - High likelihood of success. Existing businesses up and running, but not likely using best technologies, particularly those that are small enough to scale to benefit smallholder farmers. We recommend piloting an approach where we test/modify two threshing technologies along with portable systems. In parallel, we can seek to partner with long-term financing mechanism / guarantee program.

Seed potato storage - Some likelihood of success. While there are systemic issues that need to be addressed in the potato industry, there is still an opportunity for seed potato storage solutions. We recommend exploring the cooperative model and working with existing cooperatives or seed potato producer farmers to build medium scale diffused light storage structures. It may also be worth considering a pilot of a household-level storage solution, such as pit storage or a service provider storage solution, to see if it is financially viable for farmers.

Spice drying (chilies) - Some likelihood of success. We recommend exploring the potential for a chili drying facility, as there is a clear demand for high-quality chilies in the market. A photovoltaic-powered dryer or greenhouse-type warehouse with natural conventional currents could be viable solutions. The drying system could potentially be used for other crops produced in the local area, such as ginger, cassava, taro, and sweet potato.

Poultry slaughtering - High likelihood of success. We recommend setting up a small-scale poultry slaughtering facility in Bishoftu, with a capacity of up to 2 million chickens per year. Both the toll processing and trader business models are financially viable, and there is a clear demand for high-quality poultry meat in the market. The facility could potentially encourage more chicken farms to establish themselves in the area, increasing the supply of chickens for slaughter.

In all these areas, it is important to conduct thorough pilots before scaling up to ensure that the proposed solutions are financially viable and address the needs of smallholder farmers and other stakeholders. Partnerships with local organizations, businesses, and government agencies will also be critical to the success of these initiatives.

1 Grains/cereals/ pulses threshing

Research

- Similar locations and high volumes
- Potential ability for multi-crop technology
- Very high need / existing awareness – constrained by up-front capital requirements

Solutions

Small-scale thresher with transport

- Viable
- Feasible
- Desirable

Validation Question

1. Transport solutions such as the tricycle currently available?

Recommendation

High Likelihood of Success

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- Existing businesses up and running, but not likely using best technologies, particularly those that are small enough to scale to benefit smallholder farmers.
- We recommend piloting an approach where we test/modify two threshing technologies along with portable systems.
- In parallel, we can seek to partner with long-term financing mechanism / guarantee program

2 Potato storage

Research

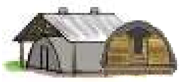
- PHL of 50% -- big need
- Technologies/solutions relatively low-cost, but may not be prioritized by farmers compared to other costs such as farm inputs

Solutions

SEED
Diffused Light Stores

- Viable
- Feasible
- Desirable

WARE (EATING)
Dark/cold rooms (charcoal, vented)



- Viable
- Feasible
- Desirable

Validation Questions

1. Will farmers be able to wait? Or do they need ready cash at harvest?
2. If able to wait, then are they willing to pay a fee / deduct a % of their crop for the service?
3. If not, are there household level / small-scale solutions that

Recommendation

Some Likelihood of Success

Amhara | Oromia | SNNP

- **SEED:** Massive need and gov't prioritization; however, concerns that promoting a local solution would hinder the introduction of a more systemic solution: a supply of quality seed to SHFs. Recommend working with seed-producer cooperatives.
- **WARE:** Open question whether farmers would truly be willing to pay for storage (whether as staple or cash crop)? Can they afford to pay and/or wait to sell? Recommend test

3 Chilies drying

Research

- Similar drying needs for all spices (e.g., ginger and chilies)
- Technologies/solutions relatively low-cost, but volumes must be big enough to justify implementation
- Storage (plastic bags) and milling are potential add-on businesses

Solutions

Greenhouse-type dryer

Viable
Feasible
Desirable

PV-powered dryer

Viable
Feasible
Desirable

Validation Questions

1. Does the farmer have “willingness to pay for service”? He/she needs to understand the benefit first.
2. Is the trader willing to pay a premium for the higher-quality chilies – without trying to take advantage of the farmer?

Recommendation

Some Likelihood of Success

Amhara Oromia SNNP

- **CHILLIES:** Potential to introduce a drying system that allows for higher price payments to farmers as a result of improved quality. Win -Win for the entire value chain. Also potential for add-on milling services.

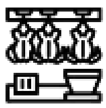
4 Poultry slaughtering

Research

- Unique value chain
- Existing poultry farmers have little access to modern slaughtering facilities, leading to biohazard/ contamination during processing
- Large market potential to supply city businesses (e.g. restaurants)

Solutions

Small-scale, semi-automated slaughterhouse facilities



Viable
Feasible
Desirable

Validation Questions

1. Survey/assessment of supply for poultry in zonal area.
2. Marketing/sales with buyers of poultry meat requires further analysis.

Recommendation

High Likelihood of Success

Amhara Oromia SNNP

- Supply of chickens is biggest risk – the production within a catchment area is lower than slaughterhouse capacity even at “small scale”.
- Test 2 models: (1) toll processing of chickens for a fee, (2) buying chickens and selling poultry meat.

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Resilient Agriculture for Inclusive and Sustainable Ethiopian Food Systems (RAISE-FS) is a four-year program funded by the Dutch Embassy in Addis Ababa and hosted by Stichting Wageningen Research Ethiopia based in Addis Ababa, to bring about transformation in the Ethiopian food system. RAISE-FS will develop and implement a demand-driven and interdisciplinary approach to Research for Food System Transformation (R4FST) and as such contribute to the Government of Ethiopia's transformational agenda.