FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

POSTHARVEST LOSS ASSESSMENT OF GREEN BANANAS IN RWANDA

JULY 2018

USAID FROM THE AMERICAN PEOPLE

HORTICULTURE INNOVATION LAB

UC DAVIS UNIVERSITY OF CALIFORNIA

Agribusiness Associates Inc.

NAEB

RWANDA AGRICULTURE BOARD RAB

UNIVERSITY OF RWANDA

FEED THE FUTURE INNOVATION LAB FOR HORTICULTURE

POSTHARVEST LOSS ASSESSMENT OF GREEN BANANAS IN RWANDA

JULY 2018

This publication is made possible by the generous support of the American people through the United States Agency for International Development (USAID). The contents are the responsibility of the Horticulture Innovation Lab's Reducing Postharvest Losses in Rwanda project and do not necessarily reflect the views of USAID or the United States Government.

CONTRIBUTORS

Commodity Systems Assessment – Bernard Rwubatse, Lisa Kitinoja, Christine Mukantwali, Eric Kabayiza, Hala Chahine-Tsouvalaki, Hilda Vasanthakaalam and Lizanne Wheeler

Value Chain Analysis – Sally Christie, Angelique Kangondo, Pascal Dukuzumuhoza, Christine Mukantwali, Eric Kabayiza, Gurbinder Singh Gill and Hilda Vasanthakaalam

Life Cycle Assessment - Jesse Sky Daystar

COVER PHOTO:

Banana delivery to a market. Photo by Jesse Daystar for the Horticulture Innovation Lab.

USAID FROM THE AMERICAN PEOPLE

HORTICULTURE INNOVATION LAB

UCDAVIS UNIVERSITY OF CALIFORNIA

Agribusiness Associates Inc.

NAEB

RWANDA AGRICULTURE BOARD RAB

UNIVERSITY OF RWANDA

Agribusiness Associates

Started by Mr. Gurbinder Singh Gill, Agribusiness Associates is an international development consulting firm focusing on overcoming the biggest challenges in the agricultural sector. The firm has special expertise in offering comprehensive solutions to the agribusiness sector for enterprise development. ABA has worked in public-private partnerships, seed industry, technology adoption, capacity building and providing strategic advisory services.

Contributors

Commodity Systems Assessment – Bernard Rwubatse, Lisa Kitinoja, Christine Mukantwali, Eric Kabayiza, Hala Chahine-Tsouvalakis, Hilda Vasanthakaalam, and Lizanne Wheeler
Value Chain Analysis – Sally Christie, Angelique Kangondo, Pascal Dukuzumuhoza, Christine Mukantwali, Eric Kabayiza, Gurbinder Singh Gill and Hilda Vasanthakaalam
Lifecycle Assessment – Jesse Sky Daystar
Reviewers- Serge Ndayitabi, Jean Paul Hategekimana, Vincent Karasira, Sharon Cyantengwa, Aloys Hakizimana, Ndilu Lea, Gerardine Nyirahanganyamunsi, Alfred Nsigaye

Acknowledgements

Our gratitude goes to the Ministry of Rwanda Agriculture and Animal Resources for facilitating its institutions, Rwanda Agriculture Board (RAB) and National Agriculture Export Development Board (NAEB) to participate in the implementation of this project. Also, thanks to the University of Rwanda (UR) for their close collaboration to make the project successful.

Thank you to the Rwanda field team: Solange Musanse, Godelieve Mukamurezi, Samuel Lusweti and Wilberforce Muyomba for their fieldwork and support during the study.

We thank the Horticultural Innovation Lab team, especially Dr. Elizabeth Mitcham and Erin McGuire for their review. Rashmi Kiran Ekka is acknowledged for her editing and compilation of the report. Serge Ndayitabi is gratefully acknowledged for coordinating all aspects of this report and for his support to the project.

Any remaining errors and omissions are the responsibility of the contributors of the report.

CONTENTS

List of Figures

List of Tables

ABBREVIATIONS & ACRONYMS

CSAM	Commodity Systems Assessment Methodology
HACCP	Hazard analysis critical control points
IPM	Integrated Pest Management
PEF	The Postharvest Education Foundation
PHI	Postharvest intervals
PTSC	Postharvest Training & Services Center
RAB	Rwanda Agriculture Board
RALIS	Rwanda Agriculture and Livestock Inspection and Certification Services
RBS	Rwanda Bureau of Standards
RPC	Returnable Plastic Crate
SSC	Solid soluble content
WFLO	World Food Logistics Organization
ZECC	Zero Energy Cool Chamber

1. EXECUTIVE SUMMARY

Bananas are a main staple crop in Rwanda, with widespread cultivation, consumption and cultural acceptance. Key challenges in the banana segment include disease, perishability and cost of transport. Postharvest in general was less of an issue for this crop than for the others, though potential for collection centers and / or centralized storage options may exist.

Recommendations for bananas for the Postharvest Training & Services Centers include supporting lead farmers; helping them to achieve a forward position in the marketing chain; and working with existing large-scale processors on their supply needs.

To understand the postharvest losses in the green bananas value chain, the project conducted three types of analysis – Value Chain Analysis, Commodity Systems Assessment Methodology (CSAM) and Environmental Lifecycle Analysis. The following graphic illustrates the losses.

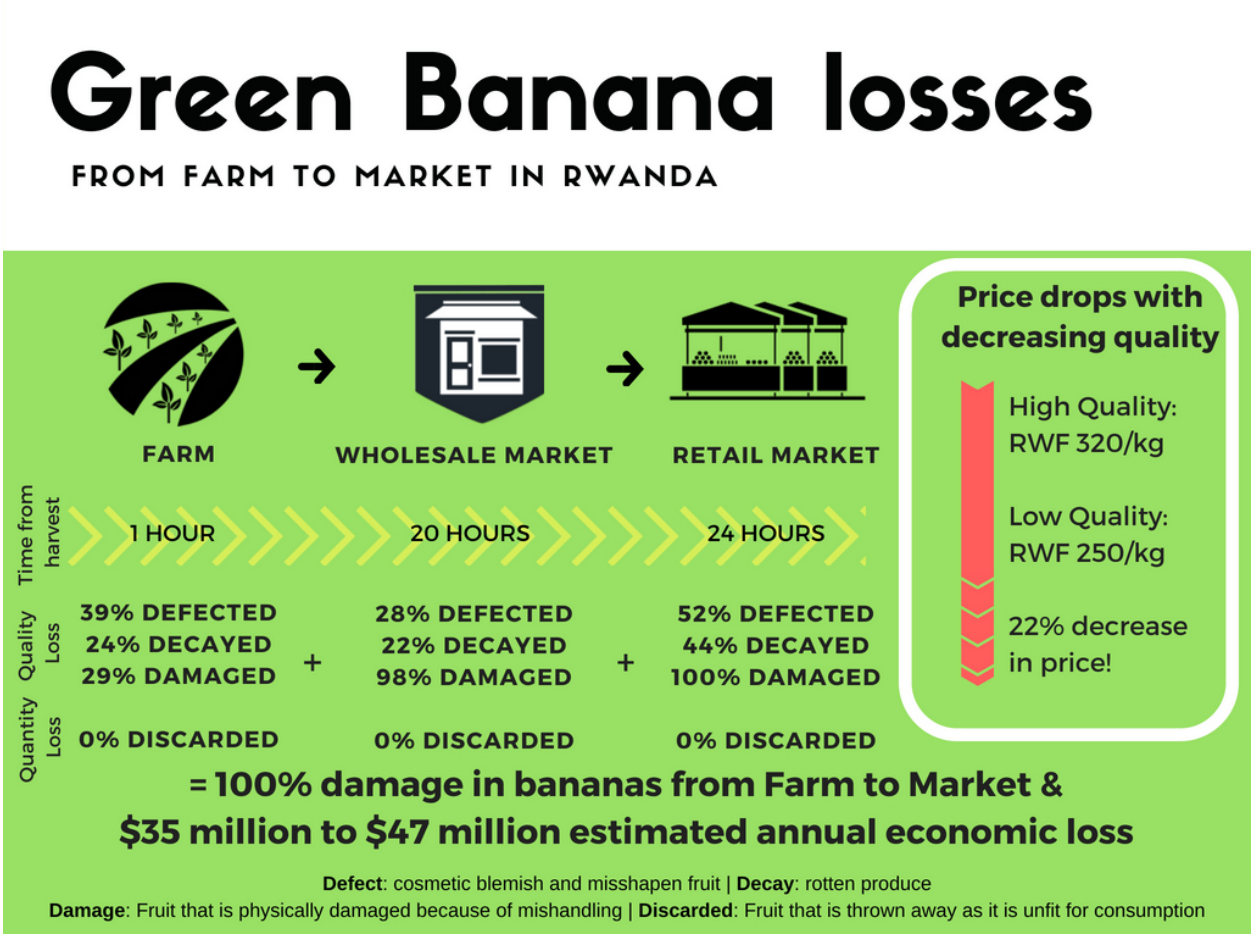


Figure 1: Green banana losses: From Farm to Market in Rwanda

Figure 2: Causes of Postharvest Losses in Photos

Summary of postharvest losses and quality problems for the crop

 Farmer Knowledge	• Harvesting practices are rough and cause damage to the produce
 Temperature Management	• Bananas are exposed to the sun during transport and marketing, and there are no cold chains or cool storage facilities for bananas,
 Transportation	• Cooking bananas are transported as bunches, and are handled roughly, leading to various losses along the chain • Bicycles and trucks are overloaded for the transport of produce for long distances.
 Farmer Organization	• Farmer cooperatives are not properly organized, which has led to lack of bargaining power for selling their produce to traders
 Processing	• There are limited processing options for cooking bananas, and poor-quality packaging.

Recommendations for Reducing Postharvest Losses

Bananas are one of the most well-studied horticultural crops, and green bananas/cooking bananas are often considered a staple food crop. Past research has identified many appropriate handling practices and improved technologies for reducing postharvest losses and maintaining quality and market value. Four major recommendations are provided to guide the project.

1	**Training of trainers (capacity building)** in improved cooking banana handling on the farm. Leaders of cooperatives involved in cooking banana production should be trained in harvest indices, apply appropriate postharvest handling techniques, use of improved containers, sorting and grading systems, use of shade during harvesting and postharvesting steps, etc.
2	**Training on methods of improved transport** for cooking bananas. Training on use of potential low-cost transport options including tricycles, bicycle trailers, and covered cargo bicycles, etc..
3	**Demonstrations that are recommended for the Postharvest Training and Services Centers** on cost effective practices for reducing postharvest losses in cooking bananas include: • Maturity indices, quality and shelf life • Improved, gentle harvesting practices • Use of shade (various types of simple, low cost structures and portable shade such as market umbrellas) • Use of improved containers for transport and marketing • Use of tricycles or bicycle trailers for improved local transport • Zero Energy Cool Chamber • Small-scale cooking banana processing methods
4	**Postharvest agri-business opportunities for cooking bananas should be promoted.** These include: • Trader/grower partnerships, where improved banana production, harvest practices and postharvest handling on the farm leads to increased profits for both the growers and the traders. • Local manufacture of cooking banana flour (with flavors/dried vegetable mixes, package sizes, types and prices targeted to local consumer preferences).

2. INTRODUCTION

Bananas are one of Rwanda's key staple crops. An estimated 80% of smallholders grow bananas and they play an important role in household food security, as 90% of the population consumes green bananas as a staple food. After beans, bananas of all types were the most important crop in Rwanda, in terms of hectares under production – 22% of all cultivated land representing 116,000 hectares in Season B (slightly higher than Season A), and production volume – 765,000 metric tons across both seasons.[1]

There are three different kinds of bananas in Rwanda: the percentage of cooking bananas produced in Rwanda is approximately 22 to 30% of the annual total (Bloome et al 2013; Jagwe et al 2009), with beer bananas being 64-65% and dessert bananas accounting for 6 to 10% annually. There are also small amounts of plantains imported from neighboring countries. This report focuses on cooking (green) bananas, but there is definite overlap in the production and distribution, with other varieties, particularly the brewing banana.

The average size of the smallholder banana plot is 0.04 hectare for small producers, and almost 2 hectares for large producers. Most bananas are produced for home consumption: approximately 80% for smallholders, though large producers sold an average of 50% of their production.

Importance of the crop in Rwanda

Cooking bananas are an important horticultural crop in Rwanda with consumption on a daily basis. The production is all year around, with harvests every month. They are produced on a total area of 320,000 ha, according to FAOSTATS (2014). Table 1 below illustrates the total production, yield and area harvested as published by FAOSTATS.

Table 1: Importance of bananas in Rwanda (FAOSTATS)

	Production in Tons	Yield in hectogram per hectare	Area harvested in hectares
2010	2.75 million	82,366	333,773
2011	3.04 million	87,649	346,411
2012	3.22 million	92,235	349,052
2013	3.29 million	96,058	342,694
2014	1.8 million	56,029	322,095

The crop is highly perishable because of a fragmented value chain and lack of utilization of

[1] Seasonal Agricultural Survey, 2015

improved postharvest technologies. Past assessments have reported 30 to 40% losses of bananas are common due to lack of temperature management and roughly handling the fruit as bunches without protective containers during transport and marketing (WFLO 2010; Kitinoja and AlHassan 2012).

Bananas are one of the government of Rwanda's "priority crops" and there exists significant potential for import substitution: in 2010, Rwanda officially imported 20,000 metric tons from Uganda[2] and the numbers would be higher if unofficial trade is included. If production were to rise sufficiently, there may exist potential for regional exports.

In recent years, overall banana production has declined, partially due to the severity of several diseases which has caused volumes to decrease, and some reports estimating a 40% decline in the last two decades, but production of cooking banana specifically is on the rise due to urbanization driving strong demand.[3]

In recent years, in line with their consolidation policies, the government has shifted production into more concentrated areas. Currently, the vast majority of banana production is in the Eastern Province.

The majority of farmers engaged in production are smallholders, but there does exist a significant group of advanced farmers, who monocrop bananas and who use improved seeds and production practices. For this group, bananas are a profitable cash crop and yields can be as high as 100 kg/plant during the rainy season, as opposed to 30 kg/ plant for unimproved varieties.

Currently the majority of cooking bananas are sold fresh and consumed with little to no processing. Significant potential does exist for transforming not just the fruit, but also the trunk and the leaves. After auto-consumption is taken into account, the majority of bananas destined for market are sold through a fragmented wholesaler / middleman / trader system, via the central wholesale markets in Kigali.

[2] Banana Value Chains in East Africa: Consumption, Productivity and Challenges, Kilimo Trust

[3] Banana Marketing in Rwanda, Burundi and South Kivu, CIALCA Project Survey Report, 2005

3. VALUE CHAIN ANALYSIS

Methodology

In order to gain the correct insights and provide the basis for analysis of key constraints and challenges, the following tools were used:

1) **Literature Review** – of Rwanda agriculture and horticulture reports to date, including the *Strategic Plan for the Transformation of Agriculture in Rwanda Phase III* and the *Draft National Horticulture Policy and Strategic Plan* (2014). Statistical excerpts from the detailed E*U Baseline Report Survey on Horticulture* (2015) were also used where it pertains to the four crops in question, and farmers in general.

2) **Interviews** - the bulk of the methodology and work came from a series of interviews with key actors at each stage of the value chain, including but not limited to:
    a. Producers / Farmers (small, medium, large; coops; companies)
    b. Input supply agents and brokers
    c. Financial institutions concerned with horticulture in general
    d. Government ministries where applicable
    e. Government institutions, including NAEB and Rwanda Agricultural Board (RAB)
    f. Agriculture Extension workers (district level)
    g. Traders in the selected crops (where applicable)
    h. Wholesalers in the selected crops (where applicable)
    i. Exporters (where applicable)
    j. Processors
    k. Transport agents
    l. Retailers
    m. Others as applicable

3) **Site visits** to farms, markets and factories

Each Value Chain analysis was developed in conjunction with a local team who were trained on the methodology, as well as with representatives of the partner organizations in the Rwanda Postharvest Solutions for Horticulture project – National Agriculture Development and Export Board, Rwanda Agricultural Board and the University of Rwanda.

Findings

Each stage of the banana value chain (Inputs; Production; Harvest and Post Harvest; Marketing and Distribution; Processing, as well as Policy/Operating Environment) is broken out and the positives of the current situation are highlighted and key challenges listed.

As much as possible the emphasis is on green cooking bananas, but fruit and beer bananas are

mentioned where applicable, and often the same challenges apply to all.

GOVERNMENT / OPERATING ENVIRONMENT

As noted above, bananas are one of five priority crops as decided by the Rwandan government**. Several government policies** aimed at intensifying agriculture are positive for the **banana** industry. MINAGRI, via RAB, takes a role in supplying pesticides and there are subsidy schemes for purchase of fertilizers. Land consolidation and village consolidation schemes also have a positive impact for bananas as well, and the government's "1 crop, 1 area" policy allows wholesalers and traders to target specific districts with concentrated production.

The government also provides subsidies for purchasing irrigation equipment, and has a policy of irrigating marshlands to provide year-round land for horticulture production (and other crops). The Seasonal Agricultural Survey of 2015 indicates only few large farmers use irrigation.

Rwanda has a well-organized **extension system** throughout the country, and because of the importance of bananas to the economy, all of the farmers we spoke to had benefited from RAB's training and seed provision for this crop.

Financing remains a key challenge for all agricultural sectors, due to the inherent riskiness of the industry. Although, the government of Rwanda has developed conducive environment for financial sector to enter into agriculture sector, the banks remain hesitant. A culture of financing groups at a village level does exist (*Ikimina* associations) and provides the possibility for producers to invest collaboratively in inputs and production materials. Financing becomes a greater bottleneck when processing / transformation projects are considered.

INPUTS

RAB provides a lot of practical support for banana farmers, and all of the farmers we spoke to had benefited from their training in IPM, production practices and supply of suckers. RAB has a department devoted just to bananas and manages a national banana germplasm collection database which tracks varieties and diseases throughout the country.

Plants mature in one year from planting to first harvest, and they self-propagate – new plants rise alongside the mature trees.

Organic fertilizer is generally considered better than inorganic, and mulching is very important in improved banana production. Both fertilizer and mulch represent the major line items in terms of expenses associated with banana production. Most producers use their trunks and leaves for mulch, but for often their needs outstrip their own production, and they need to

purchase from other farmers. Mulch is generally not sold on the open market but available locally through informal trade. If necessary, leaves and fibers can also be used for feeding livestock.

Disease is an important concern, and as noted above, the country has suffered from several epidemics, most recently and devastating Banana Xanthomonas Wilt (BWX). When BWX appears, the entirety of the banana plants must be cut down to stop the spread of the disease, resulting in huge losses for farmers and causing shortages on the market.

For control of the disease, only 22% of large farmers adopt the control measures such as uprooting affected suckers, and none of smallholder farmers use pesticides.[4]

PRODUCTION

Banana production is relatively easy and, apart from vigilance around disease and proper fertilization / mulching, production is relatively low maintenance and this was cited by most of the farmers we talked to as their number one reason for focusing on this crop.

Proper spacing is a requirement for successful production. Bananas are suitable for intercropping, but the most successful / improved farmers we visited did not do extensive intercropping, but kept the fields solely for well-spaced bananas plants. Improved farmers use sticks to support the plants against high winds.

As noted above, there is little to no irrigation, and bananas withstand drought quite well. Despite this, every farmer we spoke to cited **climate change (increasing heat and decreasing rain)** as their key challenge.

HARVEST AND POSTHARVEST

For harvest, mature bunches, weighing approximately 50 kilos, are cut from the banana plant using a machete (a staple item in almost every Rwandan farming household) or a stick. Free cut bunches run the risk of being damaged when they fall from the banana plant (though the plants are bent while being harvested). To address this issue RAB pioneered a simple stick and rope cutting system to minimize damage during harvest, but it does not appear to have become widespread.

Bananas are highly perishable, with an average of only 3 days of shelf life. We saw no storing or cooling facilities, but this is primarily because harvest is “on-demand” and straight from the

[4] Seasonal Agricultural Survey, 2015

trees.

Amongst bigger farmers, known wholesalers and banana intermediaries are in contact with farmers and bunches are bought while still on the tree, cut down, weighed and immediately placed in the truck. There is limited handling in this system.

For smaller farmers without these distribution links, they generally cut bunches in the morning of a market excursion. Bunches are packed into wheelbarrows or onto bicycles and taken to collection points or local markets. The quality of the banana deteriorates due to transportation by bicycles apart from postharvest loss (quality and quantity) and risk of accidents. Road conditions and transport issues can also affect postharvest losses.

One of the major postharvest issues is theft: given that the value of the fruit is consolidated in one bunch, and that bunch is relatively easy to cut down, and that bunch can represent 5,000 fr (approximately $6, a significant amount of cash in Rwanda), theft was cited as the number one harvest and postharvest concern by the larger farmers we talked with, especially those with plots not necessarily near the house. The cost of hiring guards, and the potential risks, were cited as the number one postharvest challenge.

Purchase of bunches is done by weight, and scales are an important aspect of postharvest. Scales are used by farmers to weigh each bunch, on-farm before sale, or at the markets, and while many farmers we spoke to had received scales as part of MINAGRI or NGO efforts, some were concerned their scales needed calibration. Larger farmers have their own scales, and some intermediaries, and most wholesalers as well.

For transport, bunches are piled into trucks. The wholesalers and traders we talked to claimed minimal losses during transport.

There is minimal sorting, especially in the on-demand systems: the wholesaler or middleman will choose the bunch they want, and those not sold will be used for home consumption. Sorting generally happens at the farm level (or even while it is on the plant Quality is generally determined by size and maturity, with the largest fruit are destined for market, and smaller ones are for home consumption. Even large farmers auto-consume a big fraction of their production, giving them a large “market” for their lower quality fruit.

The priority areas for postharvest intervention for green bananas are better harvesting, better packing, reduction of theft and staggering production and maintaining the quality of the produce throughout the value chain

MARKETING AND DISTRIBUTION

Overall, the banana marketing and distribution system is fragmented and there are no central players in the value chain to extend farmer support. Some farming cooperatives have extended into the wholesale trade, and cooperatives exclusively involved in banana trading also exist. Bananas are generally sold at local markets or at wholesale markets in Kigali (Kimirongo and Nyabugogu in particular) where they are sold to traders, retailers and larger institutions. Middlemen play an important and flexible role in this industry.

Price fluctuations are a problem, and farm-gate prices ranged from 60 frw / kg to 250 frw / kg. Some farmers refused to sell at less than 100 frw / kg, but others felt they were still making a profit at 60 frw / kg. Prices are generally set at the wholesale markets and then relayed to farmers by wholesalers or middlemen. Some farmers in more remote areas of the Eastern Province are in contact, via phone, with the wholesale markets to know ahead of time the market price before entering into negotiations with their purchasers. Mobile phones were found to be an excellent means for banana trading among the farmers.

Some of the larger farmers set prices themselves (based on information from the market in Kigali) while for others the middlemen / wholesalers set the price.

Transport costs are high for this bulky crop. Most of the wholesalers and the trading cooperatives had their own trucks.

Some of the larger farmers sold directly to large institutions (hospitals, schools). Given the decent volume of supply required by these institutions, coupled with the relative sophistication of some of the larger farmers and cooperatives, there may be some opportunity to cut out the middlemen and promote more direct sales.

As noted in the other crops, the wholesale markets in Kigali are crowded. However, the new project for the Kigali Wholesale Fruit and Vegetable market which is in the pipeline, may improve this situation.

PROCESSING

There are a range of potential products that can be made from the banana plant, Bananas are a holistic plant with many options for using both the fruit, the leaves, and the trunk, both for consumption and non-consumption. Most bananas are eaten either raw, as fruit (ripe banana), cooked vegetable, and small proportion are processed in order to get products which can be stored like flour, chips, wine, juice, etc.

The following graph outlines some of the potential products:

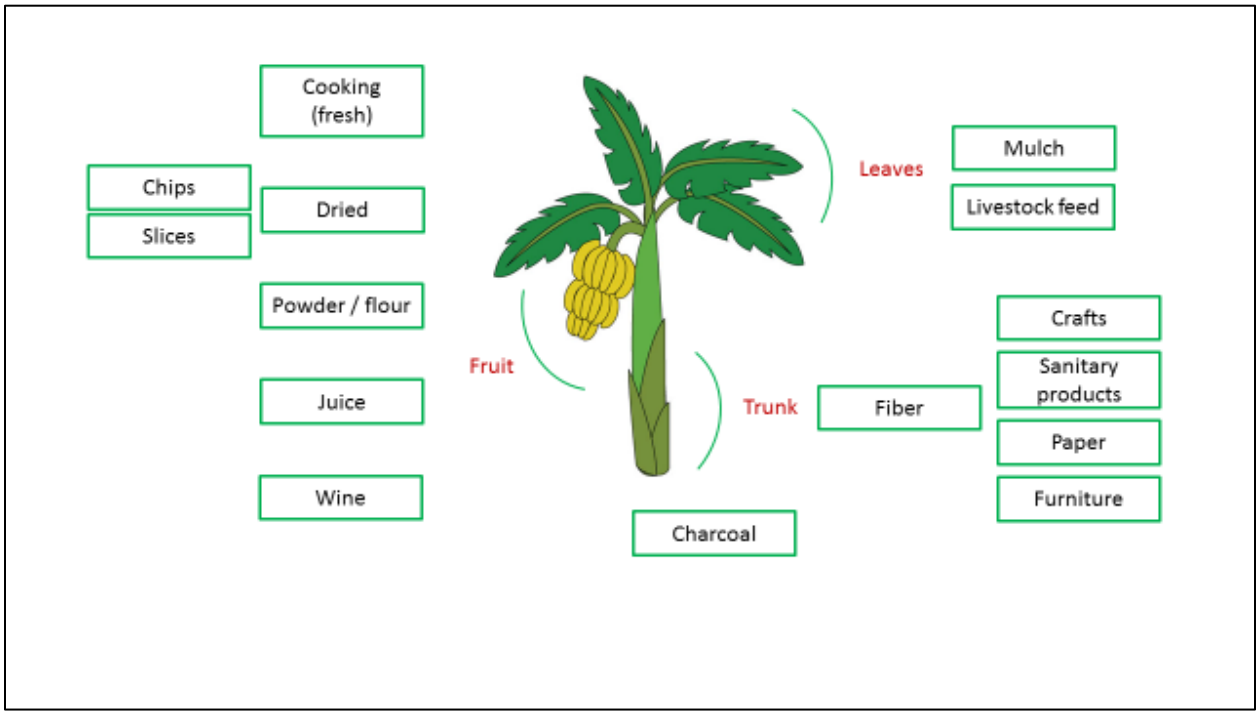


Figure 3: Banana Product Map

Excluding brewing bananas and beer, there are several banana transformation projects in Rwanda. Most current projects are artisanal level (crafts, furniture), but there does exist one semi-industrial transformer (fibers into sanitary pads – SHE factory) and there are several larger-scale projects planned, for wine and paper, but these have not yet started production. In some Asian countries, the nutrients dense flower and central stem are also utilized which can be explored.

The real market for products made from banana fibers, though the potential products are endless, remains uncertain. Similar to other vegetables such as tomatoes, bananas run the risk of supply-led, rather than market-led, investment decisions without proper strategy, based on the premise that bananas exist in great quantity and that “value addition” is the ultimate goal.

There sometimes appears to be too much emphasis on value-addition, but “value added” can also refer to a superior *unprocessed* product, meeting all of a specific buyer’s needs, that allows the producer to command higher prices over unimproved products. Venturing into processing, especially at a smaller scale, is extremely challenging, especially when market demand for the

value added products remains in question.

While some of the larger farmers have branched out into processing, it remains a side business and the only real market for some of the more innovative food products remained agricultural fairs.

In a situation of strong demand, it is possible that the best returns for a banana farmer remain in the supply of high quality fresh fruit to the local, and potentially regional, market. At the same time, in a situation of constant, strong demand, a farmer will always prefer to sell for a premium on the fresh market, rather than to a processor for a lower price.

GREEN BANANA ACTORS AND MARKET SYSTEMS

A. PRODUCERS

PRODUCER SEGMENTATION

There are several types of farmers involved in the banana industry and the following provides an overview of them. Note that our segmentation does not overlap standard classifications, but is instead a more nuanced approach intended to help segment and identify target producers for the Postharvest Training & Services Centers.

The following segmentation is also specific to bananas, and similar segmentations should be developed independently for other targeted value chains.

Small and Medium Farmers

- Focused on subsistence crops (of which bananas may be the majority) and household consumption crops
- Limited use of good agriculture practices (GAP) and low use of intensification methods.
- Sales (up to an average of 22% of their total production) primarily to local market or to smaller traders and additional intermediaries.

Producer Cooperatives / Associations

- Formed by farmers and generally focused on bananas
- Often more production-oriented than market-oriented
- Some may be large enough to own their own transport (trucks) and have strong linkages with market actors
- Able to generate large volumes

Large Farmers

Several banana farmers who we were identified as "lead farmers" and who are making a good livelihood from bananas were interviewed. They are often mono-cropping (dedicated to bananas) and employ improved production methods. There exists significant divergence between the subsistence farmer and the "specialized" farmer:

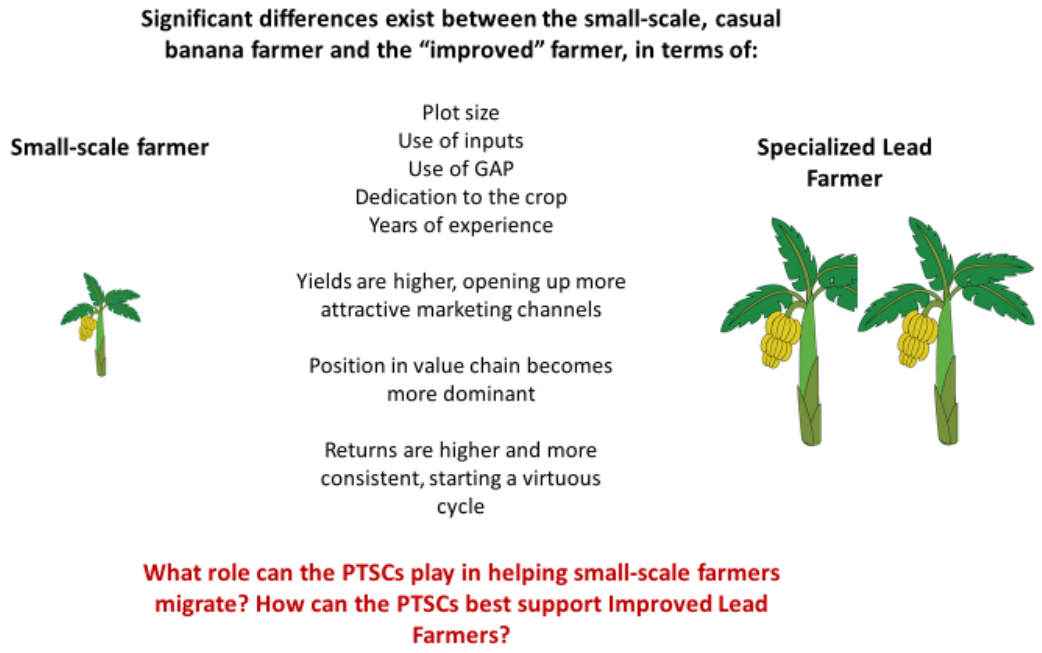


Figure 4: Specialized vs. Subsistence Farmers

Benefits of specialization

With bananas, the benefits of specialization were most pronounced. Given the risky nature of horticulture, it is not surprising there were very few large "tomato only" farmers, for example; the larger tomato farmers were also well diversified into other vegetables. However, bananas are a staple crop with year-round production and year-round demand, and we found high levels of specialization amongst larger independent farmers and cooperatives.

Support for taking a forward position

It's very easy, especially when taking a value chain approach to recommend farmers eliminate intermediaries and sell directly to consumers. For many crops, if not most, this approach may not be feasible, primarily due to insufficient volume and lack / cost of transport.

For bananas, there does appear to be an interesting opportunity for larger lead farmers to

develop more forward links, primarily because of:

- Proven track record of growing and managing a "business" – successful banana farms
- Large, constant, and focused demand from institutions (for example, schools and hospitals)
- Sufficient hectares to produce the volume required by these institutions on a weekly basis

Rather than focusing on small-scale processing projects, this would appear to be the largest opportunity to capture more value.

B. MARKET ACTORS AND SYSTEMS

MARKETING AND DISTRIBUTION MAP

The following figure provides an overview of different channels from the time the banana leaves the field:

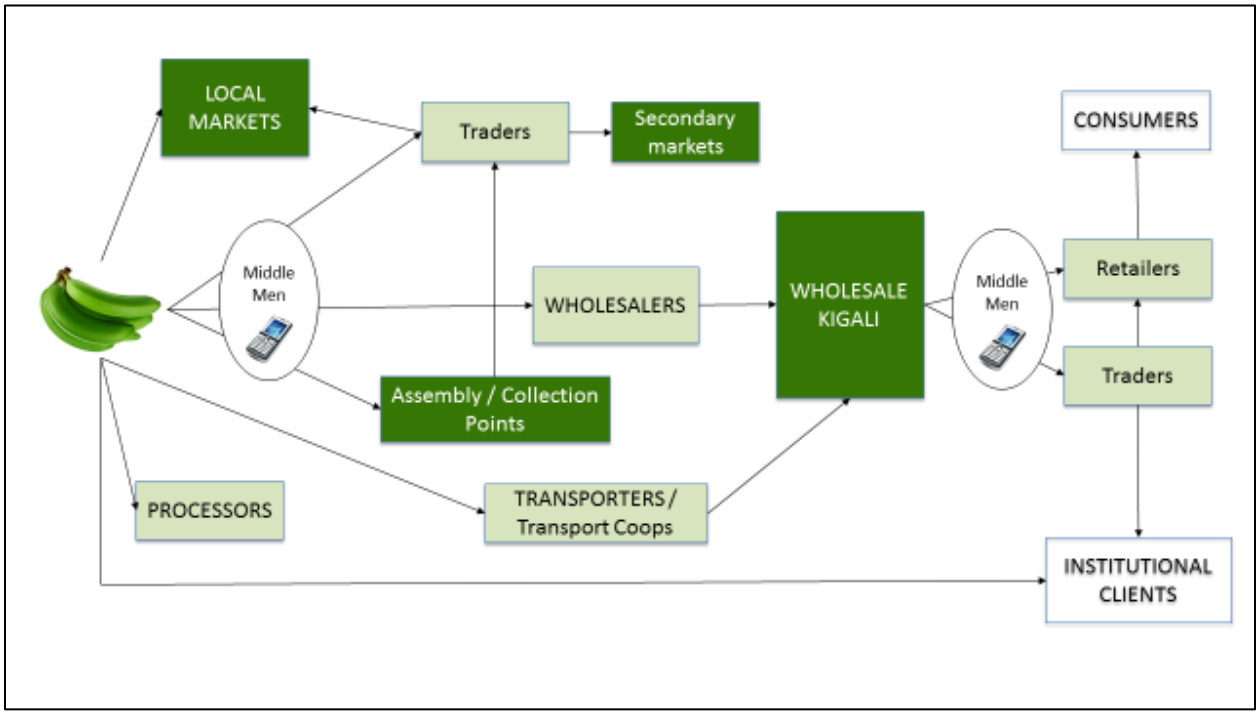


Figure 5: Banana Marketing and Distribution

OVERVIEW OF GREEN BANANA MARKETING AND DISTRIBUTION ACTORS

The banana value chain, being a large volume and dispersed one, has many different actors that fill various roles between the farmer and the final consumer. An overview of the main groups is

provided here:

Wholesalers

- Either cooperatives or individuals
- Typically focus on one region and specialize only in bananas, though may carry all three types (beer processing, cooking, fruit)
- May be backwards integrated (i.e. have their own farms and supply source); an estimated 30% of all traders (all agriculture crops) have their own farms[5]
- Extensive use of middlemen / local traders to identify where production is daily
- Buy only the bunches they want, so sorting happens at a farm level (tree-level)
- Own their own weighing scales
- Own their own trucks for collection
- Use plastic sheets to cover bananas for transport in trucks
- Have ability and contacts in neighboring countries (Uganda or Tanzania) to bring in product when their normal geographic supply is low
- Daily spot trading at major wholesale markets

Middlemen

They are involved in both production and distribution

- **Production middlemen** are in contact with producers, and either connect wholesalers to current harvests or collect harvest themselves in field; paid by wholesalers or by farmers; buy only the bunches they want, so sorting happens at a farm level
- Own their own scales even if the farmers they deal with have theirs
- Middlemen informally act as the conduit between smaller farmers, and traders and wholesalers: they negotiate prices, explain prices, act as facilitators, enforce informal contracts
- Knowledgeable about banana producers and production in his area: know who is harvesting what, how much and when

- **Distribution middlemen** connect wholesalers to retailers at various markets, central and secondary; can act as wholesalers' eyes and ears on the ground and in the markets; relationship informal and based on trust rather than contacts; paid by the wholesaler as percentage of product moved; collects money for wholesaler
- Male-dominated
- Low capital requirements and assets
- Opportunities for small entrepreneurs to opportunistically insert themselves into various positions in this chain

Market traders and retailers

- Purchase bunches by the kilo; may sell bunches or individual fruit cut from a central bunch

[5] Sabine Abewe Hategekimana, Study on Regional Agribusiness Traders

- All sales by weight, not full bunch (unit)
- Dedicated space (stalls, rooms) at major wholesale markets
- Repeat customers: individuals, traders, institutions
- Own their own scales
- May have contracts (informal, based on trust) with specific wholesalers

Overall, high levels of integration, with many actors playing multiple roles (e.g. farmer and wholesaler and retailer). Everyone interviewed was concerned about **perishability** and **price fluctuations**, as well as **access to capital**, either for equipment upgrade / purchase, or as rolling capital stock.

While price fluctuations are an annoyance, it did not appear to be a showstopper. The swings are not as extreme, and because of the relatively easy production and low input costs, and the guarantee of a sure market, a farmer will sell at any price and recoup something without too much investment.

The current banana shortage, as well as climate issues, were also on everyone's mind.

The following is an overview of two distribution channels, including prices (francs / kg):

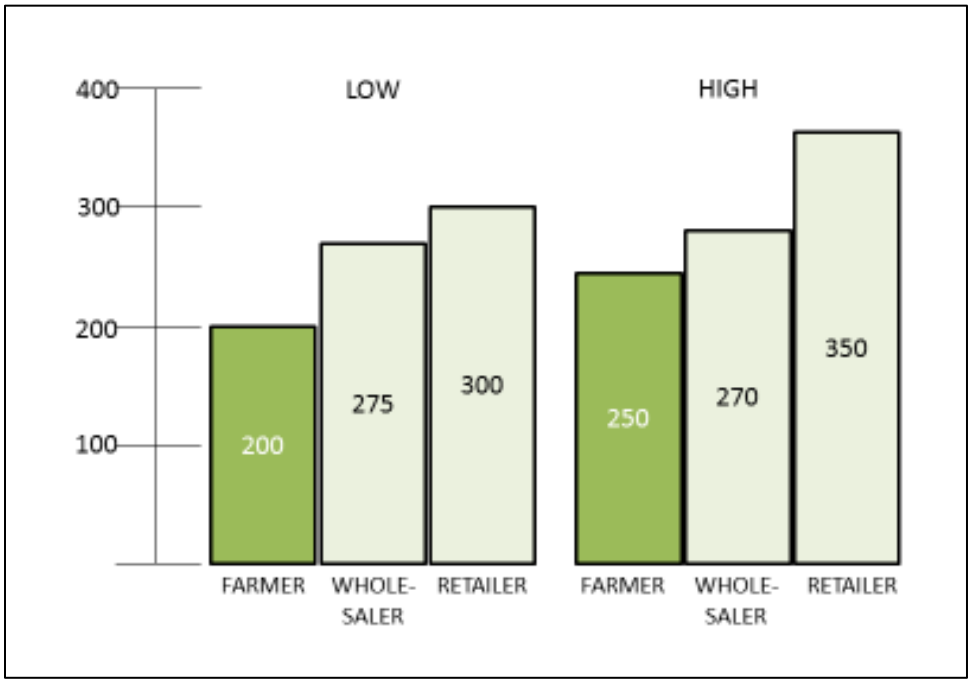


Figure 6: Wholesale Distribution Channel and Associated Value

The above figure is more representative than factual –banana distribution rarely follows such a

neat, three actor pattern – but it does show the potential value that can be captured by going straight to consumers: 100 frw/kg additional on an average farm-gate price of 200-250 frw/kg.

C. FARMERS AS PART OF THE MARKETING AND DISTRUBUTION CHAIN

Small farmers may bring their bananas directly to village markets, or to informal collection points where they may sell to traders. They may also bring their produce directly to wholesale markets (especially those in the vicinity of Kigali). There they sell to retailers, traders or wholesalers who may be agglomerating for other markets.

Once sufficient volumes are obtained, they can work more effectively with traders and wholesalers, either by selling their produce from the tree or at a nearby collection space.

D. MARKETS

END MARKETS

Local Markets – serving small villages and / or towns. The retailers in these markets generally buy directly from farmers or via small-scale traders. The prices in this market are significantly lower than in the wholesale markets in Kigali (for example, a spread of 120 frw/kg vs. 250-300 frw/kg). They are generally open-air and have no cooling or storage facilities. Traders may buy from these markets for further sale in Kigali (depending on distance).

Daily spot wholesale markets, in Kigali – these are way the vast majority of bananas are sold in the Kigali area. Many of these wholesale markets operate outside of large retail markets, and finish their business before the retail market opens. Traders buy from these markets, and often sell to retailers within. Larger retailers may buy directly from wholesalers.

These markets, either at the wholesale or retail time, also serve as distribution points for smaller kiosks, shops, street sellers, etc., as well as to restaurants and end consumers.

These markets are open air (wholesale) then covered (retail), generally chaotic, have no cooling or sorting facilities, or washing facilities of any kind. Once purchased by traders, the trader / retailers sell by the bunch or, when the consumer is closest, start by cutting off several bananas from the bunch.

Institutional clients – Hospitals, bars, institutions, schools, restaurants represent an important market for bananas. Many of the traders and retailers we spoke to, as well as a few larger

farmers, had contracts with hospitals, schools or restaurants for the provision of a fixed amount of bananas every week (ranging from 100 kgs to 500 kgs a week). Because of the large, steady and constant demand from this players, there is potential for more cooperatives or larger farmers to establish direct links and eliminate the middlemen.

Regional exports - There may be potential markets in neighboring countries, particularly as demand grows, but for the moment, and specifically due to the shortage situation, the study team experienced while conducting this study, regional exports are not a priority. Given the volume of imports, however, there should be a medium to long-term play in this area.

Recommendations

This report focuses on recommendations and interventions at a farmer level (rather than a national level) and mostly on areas where the PTSC can add value and intervene. Nonetheless we anticipate that not all recommendations will be under the scope of the project, and that one key activity will be prioritizing the interventions and developing a schedule for their implementation.

At a national level, the government's priorities on bananas (as summarized in the Agricultural Strategic Plan[6]) are summarized here:

- More farmer field schools
- Include bananas for irrigation schemes where applicable
- Better quality planting materials for bananas
- Feasibility study on banana chips and dried bananas (fruit)

The PTSC project should seek to support these initiatives wherever possible.

A. VALUE CHAIN INTERVENTIONS

INPUTS & PRODUCTION – RECOMMENDATIONS

Potential Project-Level Interventions

- Work with RAB on disease prevention initiatives and programs, specifically for BXW
- Identify barriers to increasing organic fertilizer supply and mulch supply
- Work with farmers on IPM and good production practices
- Develop training programs to move farmers from basic to improved banana cultivation
- Engage lead "specialized" farmers in activities of PTSC

[6] Strategic Plan for the Transformation of Agriculture in Rwanda Phase III, MINAGRI

HARVEST AND POST HARVEST RECOMMENDATIONS

Potential Project-Level Interventions

- Training on banana harvest and postharvest best practices, both at the Training Center and via partnerships with village-level extension services
- Support RAB's program to improve harvesting methods
- Investigate options for improving collection and collection spots for smaller and medium farmers
- Investigate innovative transport solutions
    - Leasing subsidies for bikes or scooters or wheelbarrows
    - Options for larger farmers to engage own transport
- Develop and train small farmers on best biking solutions for carrying bananas
- Investigate options to reduce theft
- Support the formation of purchasing groups for harvest and postharvest equipment
- Horticulture Discretion Fund
    - Small funds to disperse money for postharvest equipment to qualified producers
    - Scales, wheelbarrows, sticks

MARKETING & DISTRIBUTION

Potential Project-Level Interventions

- Work with larger farmers to develop sales channels with institutions to eliminate middlemen
    - Feasibility studies, client engagement training, direct contact with targeted institutions, etc.
- Support development of spot checkers in markets relaying prices to farmers, for bananas as well as other crops

PROCESSING RECOMMENDATIONS

Potential Project-Level Interventions

- Quantify value of banana tree, including leaves, trunks and fruit in order to train and engage farmers in looking at overall value of their crop, including mulch
- Support existing and new investments in processing
    - Rather than promote small scale processing, PTSC should work with current large-scale investors (SHE) and potential projects (wine, paper) on their supply requirements
    - Position PTSC as trusted intermediary between suppliers and processors, to highlight the key role PHH takes in guaranteeing consistent volume and quantity
- Incorporate potential investors in this space in the Postharvest Training and Services Centers' activities
- Support attendance at food fairs for small-scale processors

Nevertheless, the PTSC should take an interest in existing processors, especially the larger scale ones, and interest them in what they can do to increase their supply:

B. PRODUCER BUSINESS CAPACITY BUILDING INTERVENTIONS

In order to increase producers' business skills and give them more of a marketing mindset, crucial for success in horticulture, training programs including the following subject matter could be developed by the Postharvest Training and Services Centers:

- Understanding price fluctuations, demand and supply
- Understanding value chains and pricing
- Dealing with traders and marketing agents
- Developing farm calendars and operational plans
- Benefits of collaboration and clustering, for purchasing and increasing industry power
- Finances: Calculating profit and loss and tracking expenses
- Production planning and harvesting scheduling
- Accessing support and resources
- Further processing and value addition
- Strategic thinking and long-term planning
- Legalities and contract review

4. COMMODITY SYSTEMS ASSESSMENT

Methodology

Commodity Systems Assessment Methodology is a step-by-step methodology for describing and evaluating the planning, production, postharvest handling and marketing of agricultural commodities. The modified CSAM (Lagra, Kitinoja and Alpizar, 2016) includes interviews of stakeholders, observations of handling practices, and direct measurements of quality and quantity losses on farm, at the packinghouse, and at the wholesale and retail market levels (for domestic markets). The field based measurements at the farm, wholesale and retail markets will increase the knowledge base and help to identify priority postharvest problems that currently limit market access for small farmers and rural marketers.
Results from the rapid assessment provides input we can use to promote technology awareness, adoption and utilization, as well as answer key research questions to inform the project and the postharvest subsector in Rwanda.

The CSAM report includes:

- The average and range of postharvest losses
- Losses segregated by category (physical injury, pathological disease, insect damage, water loss, other) at each stage in the postharvest value chain
- The estimated loss of market value for the crop
- Recommendations for reducing postharvest losses.

The districts that were included in the CSAM study include: Gasabo, Nyarugenge, Bugesera, Rwamagana and Gicumbi.

The goal of the Cooking bananas assessment was to assess postharvest losses on a random selection of 10 farms and 10 markets (wholesale and retail marketplaces) via direct measurements and observations. CSAM interviews were conducted with 12 persons, via a stratified sample of known experts, extension workers, farmers, traders, processors and marketers. The focus of the CSAM study was on green bananas/cooking bananas, but the findings on postharvest handling, quality and marketing also can be applied as well to other types of bananas (dessert or fruit bananas).

Interviews and observations identified several key issues, including diseases and damage occurring during production, lack of training for workers (very rough handling) and use of inappropriate practices (over-loaded transport vehicles, exposure to sun, damage during transport, food safety issues etc.).

CSAM data collection methods and protocols

CSAM is a systematic process of using surveys, interviews and observations to collect data on the key aspects of the value chain, including production, postharvest handling and marketing. It considers the entire commodity system, from planning and production to processing and marketing, but it will focus more on the postharvest and marketing aspects trying to determine the relative costs of any potential or observed changes in handling, containers, value addition or marketing practices.

A complete CSAM, collects data at 26 points, along the value chain, as shown in the image below.

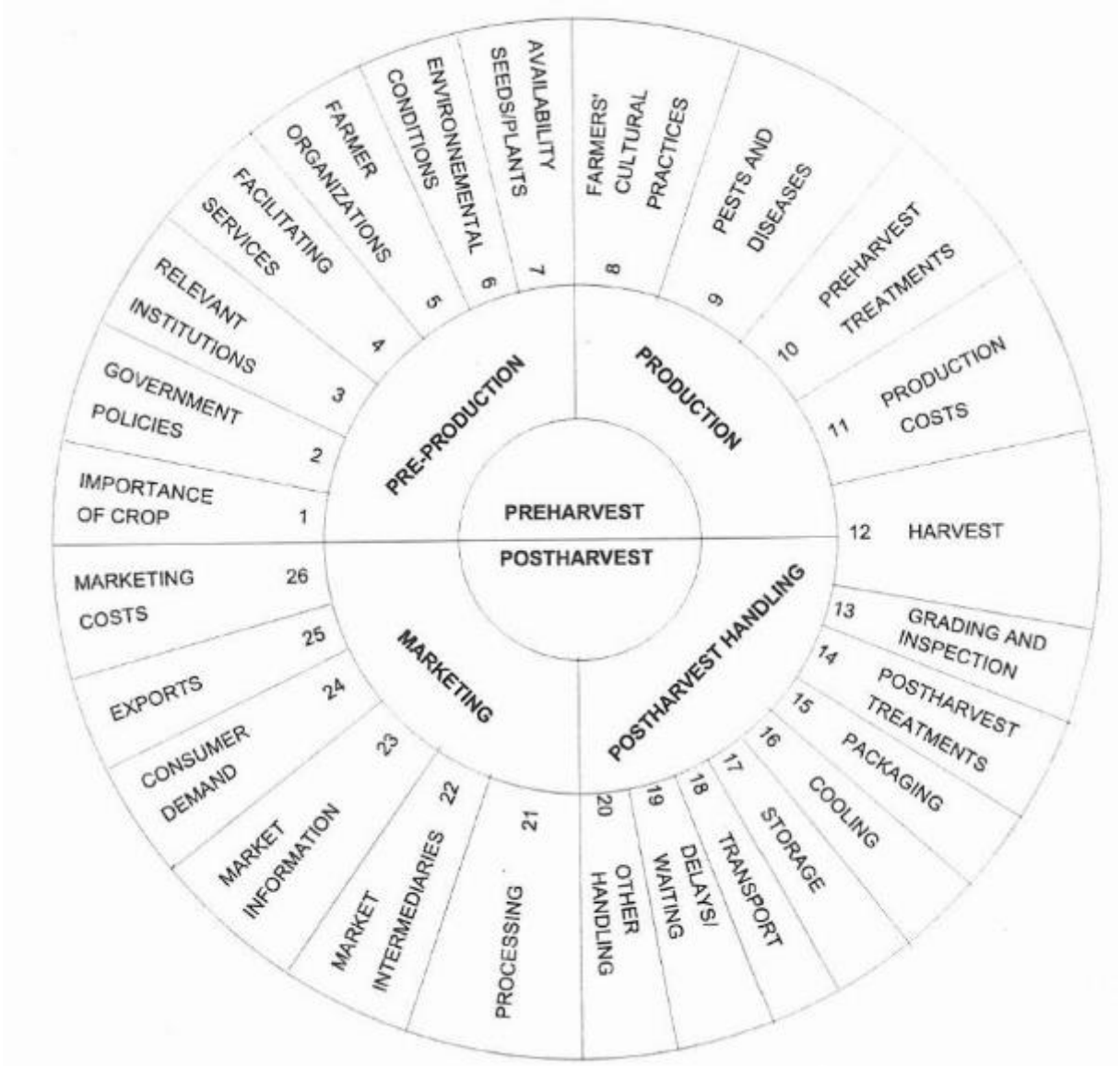


Figure 7: Principal components of a CSAM (LaGra 1990)

Data on the cooking banana value chain in Rwanda was collected via interviews following a set of written questions (Annex1A), observation, and field measurements. Questions related to production are asked mainly to farmers; marketers are asked about postharvest handling and marketing and researchers, project staff and/or extension workers about the entire system. A literature review of published articles or unpublished documents, review articles were also used as source of information to complete this report.

Additionally, there are worksheets used for on-farm (Annex 1B), wholesale (Annex 1C) and retail market (Annex 1D) data collection on postharvest losses, quality characteristics, market

value changes, general shelf life, and a worksheet on the costs/benefits of potential changes in practices (Annex 1E). The protocols for using the data collection worksheets are included in Annex 1F.

Results from these rapid assessments provided input we can use to promote technology awareness, adoption and utilization, as well as answer key research questions to inform the project.

Tools used to measure losses

CSAM field assessment was conducted with a set of tools that helpedto assess quality and losses. (Annex 1E)

- Scales to weigh loss caused by postharvest practices
- Cameras to document postharvest handling practices during data collection
- Digital thermometer (temperature probe) to measure the temperature and the relative humidity of the environment and the temperature of the cooking bananas
- Quality rating scales and color charts (maturity indices).

Site selection for the Green Bananas CSAM study

The team surveyed the country and identified and labeled attributes to the principal growing areas for cooking bananas.

The process was as follows:

- The typical production areas were identified. These included areas that were representative of the Rwanda domestic trade.
- The major postharvest chain points from farm to retail were identified, with those representing the greatest percentage of postharvest losses targeted for study.

At "**Wholesale pick up" Point/ Collection point/Aggregation point**. This point is just a place without infrastructure located nearby farming places. Small scale farmers or groups take their produce to the pick up point that is usually located 1 to 3 km from the farming area. Transportation to this point is by bicycle or foot.

At the **Wholesale market:** Wholesalers take produce from: Regional and Local market. Capacity of trucks used: Short: 5T-7T, Long: 12T. Wholesale market is the space where traders can take produce for local sales. Generally, wholesalers are the only ones having trucks for transportation (90%).

Retail market is divided into following categories:
1. Street vendors: mobile, walking through the market or along the roadside (retailers hold from 5kg to 10kg of produce composed by 4-5 types of produce such as cabbage, fruits, tomatoes, bananas and fresh beans.
2. Stationary vendors (retailers): stationed outside the wholesale market,.
3. Stationary vendors inside the market.
3. Boutique: small stores toward the city having crops with value around 1,000,000 Rwf annual turnover and they transport produce by motorcycle, bicycle or shared pickups (potential capacity: 100-200 kg/day)

The districts that were included in the CSAM study include:
Gasabo,
Nyarugenge,
Gicumbi
Rwamagana
Bugesera

Sampling protocols (see Annex 1F and Annex 2)
The goal of the assessment was to sample postharvest losses for a random selection of 10 farms and 10 markets (wholesale and retail marketplaces) via direct measurements and observations. CSAM interviews were conducted with 10 to 15 persons, via a stratified sample of known experts, extension workers, farmers, traders, processors and marketers.

Findings

The following is a summary of the major findings for the crop. Interviews and observations identified several key issues, including diseases during production, lack of training for workers (very rough handling) and use of inappropriate practices (exposure to sun, damage during transport, food safety issues).

There were seven major reasons for high postharvest losses for cooking bananas in Rwanda**:**

1) Kirabiranya disease, wind damage and insect damage during production

Figure 8: Wind damage to banana leaves

2) Rough harvesting and poor postharvest handling practices - Farmers sometimes drop produce. They lay the harvested bunches on a layer of mulch to avoid mechanical damage. However the mulch sheath can be unsanitary and spread disease.

Figure 9: Harvested bunch laid on a layer of mulch

3) Use of no containers (handling bunches without any protection)

Figure 10: Bicycle loads from farm to market near Gicumbi local market

Figure 11: Truckload of cooking bananas arrives at the wholesale market in Kigali

5) Damage during transport (compression damage, bruising of fruits) – this leads to 50 to 100% damage, 22 to 44% decay, 22% loss in market value


Figure 12: Damaged cooking bananas

6) Lack of the use of shade or any kind of temperature management – Lack of temperature management speeds ripening and deterioration. Banas are sometimes put under shade, however there are no storage facility. There are no delays for farmers after harvest as they usually harvest when the buyer is ready to transport the produce. However wholesales sometimes wait for 2 days and retailers for 4 days before the produce is sold.

7) Lack of processing options, poor hygiene, poor quality packages – There is a lack of large-scale modern processing for green bananas. Small scale processors lack hygienic conditions for processing and use poor quality packaging which is usually low quality brown paper bags wchih are stapled close. There is a consumer demand for processed cooking bananas.

Figure 13: Manual peeling and slicing of green cooking bananas for small scale flour processing in Gicumbi.

The traditional method for processing Green Banana Flour is as follows:

1) Washing
2) Peeling
3) Chopping
4) Soaking - soak the cut slices in clean water to prevent browning
5) Drying - drying takes 3-7days using sun
6) Milling via pounding

The main observations by CSAM component are highlighted below.

Table 2: CSAM Findings Summary - Causes and Sources of Losses for Green Bananas in Rwanda

CSAM Components	Interviews	Observations	Recommendations
PLANNING/ PRE-PRODUCTION	● Most of current planting materials are devastated by "Kirabiranya" disease (Xanthomonas wilt) ● Planting materials are available but expensive	● No known preventive practices for "Kirabiranya" disease	● Promotion of planting material nurseries as agri-business opportunity
PRODUCTION	● Heavy winds and cold rainstorms can damage the crop during production		● Windbreaks (living trees, hedges) can reduce wind damage, storm damage
POSTHARVEST	● Wholesalers do not care about quality or losses (they can sell everything and report that they have no losses)	● Rough harvesting, damage to bunches from cuts and drops ● Rough handling of bunches, with nearly all of the crop damaged by the time it gets to the retail market ● No containers are used for transport, bunches are piled on an open truck bed or strapped to a bicycle ● Produce is exposed to direct sun during delays	● Gentle and careful harvesting ● Gentle handling and gentle transport to reduce bruising will also help to slow ripening ● Use of shade to provide cooling ● Use of cargo tricycles and shade coverings to better distribute load and protect fruits from damage during transport
MARKETING	● All the produce can be sold, but yellowing/ripening or damaged/softening fruits are sold at a lower price/kg	● Produce is exposed to direct sun during marketing ● Mixed lots of fruits & vagetable for sale in	● Use of shade ● Gentle handling to reduce bruising and slow ripening ● Protection from exposure to ethylene will slow

	(22% discount)	marketplaces expose green bananas to ethylene ● Lack of options for processing ● Poor hygiene during small scale processing ● Local packaging options are limited and packages are of poor quality	ripening (and protect market value) ● Promotion of locally processed products (green banana flour, dried ripened fruits) ● Promotion of improved packaging for extended shelf life and quality maintenance

Postharvest Quality and Food Safety

Those interviewed during the CSAM process described how, all along the whole value chain, the laborers (farm family members or hired help) are not trained to handle the produce well. Bananas are dropped, allowed to touch the soil, and handled roughly.

Alternatively, improved handling methods would reduce the crop losses and improve food safety.

The Journey from Farm to Market

The size of the cooking banana farms included in the sample for data collection measurements ranged from 1 to 2 hectares (average size 1.8 ha). The range for the distance to market was 1.5 to 58 km (average distance = 42.8 km). The data collected on farms was either during or within 1 hour of the harvest.

Some of the fruits moved through a local or regional "wholesale pickup point" or collection center, which were outdoor areas located near a major road but without any formal packing facilities. Most of the fruits were transported by growers or small scale traders as bunches on bicycles or in small vehicles to the wholesale or retail markets. Selling was generally completed by the end of the 2nd day (24 hours after harvest).

Quality characteristics such as ripeness and firmness were measured on the farm and in the marketplaces, and were determined to be uniform (100% dark green, hard).

Table 3: Quality characteristics for cooking bananas in Rwanda

Cooking bananas	Relative perishability*	N	Air Temp °C	Pulp Temp °C	Package protection**	Color	Firmness
Farm	3	10	27.1	28.2	1	Dark green	5
Wholesale market	3	5	26.3	27.4	1	Dark green	5
Retail market	3	5	24.6	24.4	1	Dark green	5

* 1=low, 3=moderate, 5=highly perishable

** 1= low, 3 = moderate, 5 = excellent protection

Firmness rating: 5=hard to 1= very soft

Postharvest losses for Cooking Bananas

The measurements of percent discards, defects, decay and mechanical damage for cooking bananas in Rwanda are summarized in the table below. Damage and defects were extremely high, reaching 100% by the time the cooking bananas reached the retail market. This damage, due to rough handling and bruising, generally resulted in a lower sales price rather than as discarded produce. Only the very worst quality, inedible produce was discarded.

Table 4: Postharvest % losses for cooking bananas in Rwanda

Cooking bananas	Relative perishability *	N	Avg Time from harvest	Ripeness	% defects	% decay	% mechanical damage	% sorted out/discarded before sale
Farm	3	10	1 hour	100% dark green	39%	24%	29%	No sorting
Wholesale market	3	5	20 hours	100% dark green	28%	22%	98%	No sorting
Retail market	3	5	24 hours	100% dark green	52%	44%	100%	No sorting

* 1=low, 3=moderate, 5=highly perishable (red ripe)

These findings are similar to those reported for bananas in Rwanda during past assessments (WFLO 2010; Kitinoja and Alhassan 2012; Kitinoja and Kader 2015). Mechanical damage is extremely high due to rough handling and the use of poor quality containers. Mechanical damage is known to affect flavor, as bruising is related to the development of off-flavors in horticultural crops (Kader 1986).

Estimated value of postharvest losses

The damage observed in the farm during harvest by the CSAM team was enormous (ranging from 10 to 75%). The market value of the cooking banana crop decreased as the quality decreased, allowing for improved postharvest handling and investment in improved containers. Excellent quality cooking bananas could be sold in the retail markets for 320 Rwf per kg, while damaged or yellowing fruits sold for 250 Rwf/kg.

If the cooking banana crop in Rwanda is experiencing a similar loss in quality during the farm to market period as measured in this study (where 100% of the crop is damaged by the time the crop reaches the retail market), this equates to a cumulative loss in market value of 22 to 30% (the typical portion of banana production that is cooking bananas). If the annual production of cooking bananas is 400,000 to 540,000 tonnes, this equates to a loss in market value of $US35 to 47 million per year.

Table 5: Estimated range of the value of postharvest losses of cooking bananas in Rwanda

Annual Production (2014) 22% to 30% of 1.8 million tonnes of banana production in total	Market value range (high quality)	Market value range (low quality)	Annual economic loss in Rwf	Estimated Annual economic loss in $US
400,000 tonnes to 540,000 tonnes	320 Rwf/kg	250 Rwf/kg		
400,000,000 kg to 540,000,000 kg	128 billion Rwf to 173 billion Rwf	100 billion Rwf to 135 billion Rwf	28 billion Rwf to 38 billion Rwf	$35 million to $47 million

800 Rwf = $US 1

Costs and Benefits of improved postharvest practices for cooking bananas

The first example is for the use of shade to protect the banana fruits during delays or marketing. Keeping produce in the shade can help to reduce pulp temperature by 10 to 15°C. For small scale farmers, this shade structure is simple and affordable technology. It will return its cost after 6 uses. Each subsequent use generates an additional $9 per load of 100kg.

Table 6: Cost Benefit Analysis - Use of shade for harvested bananas in Rwanda

Start with 100kg	Current Practice	New Practice
	Leaving piles or containers of bananas in the direct sun	Use of shade to provide lower temperature and slow ripening/yellowing of produce during delays or distance marketing
COST		
Simple shade structure, portable	No cost	$US 50
BENEFITS		
% Loss	30%	10%
Amount to sell	100 kg	100 kg
Value per kg (excellent quality)	$0.31 (250 Rwf)	$0.40 (320 Rwf)
Total market value	$31.00	$40.00
Relative profits		+ 9.00
ROI		6 uses fully pays for the shade structure, each subsequent use generates an additional $9 per load of 100kg.

The second cost/benefit example is for the use of improved containers.
Transporting cooking bananas to market with plastic crates (smooth on the inside surfaces and vented on the sides) will prevent damage during packing and transportation and allow fruits to have good ventilation during delays and marketing. This simple technology will reduce the losses by from 100% damage to less than 10% damage and increase the earnings of the farmer/trader. Only 10 uses will fully pay the plastic crates, subsequent uses will generate an additional $9 per load of 100kg.

Table 7: Cost Benefit Analysis - Use of traditional baskets versus plastic crates from farm to market

Start with 100kg	Current Practice	New Practice
	No containers are used in transport of bananas to market: bruised and damaged during packaging, transportation, marketing, suffer from decay	Plastic crates smooth inside surfaces and vented sides prevent damage and allow bananas to have good ventilation
COST		
10 plastic crates shallow size for delicate crops ($US 9 per piece)	No cost (reuse enormous, old baskets many times)	$US 90
BENEFITS		
% Loss	22% loss in value	
Amount to sell	100 kg	100kg
Value per kg (excellent quality)	$0.31 (250 Rwf)	$0.40 (320 Rwf)
Total market value	$31.00	$40.00
Relative profits		+ 9.00
ROI		10 uses fully pays for the plastic crates, subsequent uses generate an additional $9 per load of 100kg.

The third cost/benefit example estimates the returns on investment for small scale processing of green bananas to flour. Approximately 10kg of fresh fruits are required to produce 1 kg of flour.

The processed/packaged flour product generates nearly twice the revenue compared to selling the fresh green bananas, and nets an additional $28 per 100 kg batch of fresh fruits.

Table 8: Cost Benefit Analysis - Processing green bananas to flour

Start with 100kg	Current Practice	New Practice

	No processing: purchased fruits are bruised and damaged during packaging, transportation, marketing, suffer from decay	Processing to flour, packaging in high quality metal foil zip-lock reusable pouches.
COST		
100kg @ 320 Rwf/kg	32,000 Rwf	32,000 plus labor (4 hours) 1200 Rwf ($1.50)
Packaging 20 cents per pouch		1600 Rwf $2 for 20 pouches
BENEFITS		
% Loss	22% loss in value	
Amount to sell	100 kg	10kg (20 pouches of 500mg each)
Value per kg (excellent quality)	$0.31 (250 Rwf)	$6.25 (5000 Rwf)
Total market value – costs	$31.00	$62.50 – 3.50 = $59
Relative profits		+ $28.00
ROI		Immediately pays for labor cost, generates an additional $28 per load of 100kg.

Recommendations

Postharvest technologies for green bananas recommended for Rwanda:

1) Evaporative cooling systems

There is need of cooling facilities put in place at the farmer's collection points to reduce losses of moisture and direct sunlight to keep the temperatures of bananas cooler by the time that they reach the consumers. If there are reliable cool chain facilities which have regulated temperatures that are favorable for fresh green bananas and also which is closely monitored starting from the evaporative cooling system at the collection points to the cold store trucks there would be limited loss of cooking bananas.

Introduction of evaporative cooling system will greatly reduce losses of produce and the cooking bananas will ripen more slowly and will have a longer shelf-life from picking time. A Zero Energy Cool Chamber (ZECC) that doesn't require any power to operate can keep the produce stored in

the chamber cool. Rwanda's climate (mild temperatures and mid-range relative humidity) provides good conditions for evaporative cooling. These technologies and several other cold chain management options have been fully described in Kitinoja (2013), Kitinoja and Thompson (2008) and Winrock (2009).

2) Plastic crates

The introduction of reusable plastic crates in the supply chain of bananas requires a closed system to prevent loss and damage and theft. This needs an active management system put in place for managing and control of crates, which could be supported and funded by partners in the bananas supply chain who are transporters, suppliers, traders, and customers. The system should be a reliable system to audit all crates in circulation, the crates chosen should be crates that can easily be stacked and fitting well to ease transportation and easy to move from one point to another they need to have strong handles to carry. Packaging and transport of cooking bananas in plastic crates potentially in combination with insulation materials plastic crates will be a durable solution to losses in the production value chain. The key to success will be to introduce harvesting crates which are well aerated and can be properly stacked. PEF published a White Paper on the use of returnable plastic crates (Kitinoja 2013) which can be used as a training guide.

3) Processing and packaging

Processing and packaging of cooking bananas is having challenges due to lack of sanitation and food safety issues, use of poor quality packaging. The farmers will need to provide a continuous supply to the industry for the industry to be sustainable. Packages need to protect the flour or dried products from light, insects and oxygen.

Table 9: Identification of research needs for cooking bananas in Rwanda

No	Research needs	Comments based on observations and interviews
1	Preventive practices to Kirabiranya disease	No known preventive practices to Kirabiranya disease
2	Development of resistant planting materials to Kirabiranya disease	Most of current planting materials sometimes are still devastated by Kirabiranya disease
3	Making of various cooking banana food products	Almost all of cooking banana is unprocessed

4	Preservation of raw cooking banana	Farmers/Wholesalers/Retailers are obliged to sell raw banana in less than 3 days

The following are provided as guidance for reducing cooking banana losses in Rwanda:

Table 10: Identification of training needs for reducing postharvest losses

No	Training needs	Comments based on observations and interviews	Target group
1	More and regular trainings on updated cooking banana cultivating and postharvest practices	The trainings are not enough and are not offered on time basis.	Farmer
2	More and regular trainings on updated practices fight and/or control Kirabiranya disease	The trainings are not enough and are not offered on time basis.	Farmer
3	Trainings on updated cooking banana transportation and storage.	The trainings are rarely offered.	Sellers/ transporters
4	More and regular trainings on updated cooking banana breeding practices	The trainings are not enough and are not offered on time basis.	Farmers
5	Gentle handling during harvesting	Some bananas are cut by machete and/or mechanically injured when harvesting, or when dropped to the ground.	Farmer/sellers
6	Adaptation of cool chain, beginning with early morning harvesting use of shade	Harvested banana stay long under sunlight during picking, packing, transport and selling.	Farmer/retaile r
7	Improved processing methods and hygiene	Methods and conditions lead to poor quality products and food safety issues	Processors

Advocacy issues affecting the postharvest losses of crop

The following are advocacy issues/enabling environment issues for reducing postharvest losses

of cooking bananas in Rwanda.

- Increase access to improved varieties of cooking bananas (pest resistant, high quality fresh market, plus varieties for processing) at reasonable cost for growers
- Recruitment of more number of agricultural technicians at sector and cell levels, plus support for their making more field visits
- Improving rural roads to reduce delays and minimize rough transport
- Promoting the manufacture of plastic crates in Rwanda
- Promotion and investment in a cool chain for postharvest handling, storage and transport of perishable foods
- Investment in appropriate, high quality locally manufactured packaging (reusable, recyclable)

While the focus of this CSAM study was on green bananas/cooking bananas, the findings and recommendations on postharvest handling, quality and marketing also can be applied as well to other types of bananas (dessert or fruit bananas).

RECOMMENDATIONS FOR REDUCING POSTHARVEST LOSSES IN RWANDA PROJECT

Past research has identified many appropriate handling practices and improved technologies for reducing postharvest losses and maintaining quality and market value. Recommendations for improved handling for cooking bananas are similar to those for reducing losses in fruit bananas (sweet, dessert types), beer bananas and plantains.

Four major recommendations are provided to guide the project.

1) Training of trainers (capacity building) in improved cooking banana handling on the farm Leaders of cooperatives involved in cooking banana production should be trained in harvest indices, postharvest handling, use of improved containers, sorting/grading, use of shade.

2) Training on methods of improved transport for cooking bananas – potential low cost transport options include tricycles, bicycle trailers, and covered cargo bicycles.

3) Demonstrations that are recommended for the Postharvest Training and Services Centers on cost effective practices for reducing postharvest losses in cooking bananas include:

- Maturity indices, quality and shelf life
- Improved, gentle harvesting practices
- Use of shade (various types of simple, low cost structures and portable shade such as market umbrellas)
- Use of improved containers for transport and marketing (plastic crates)
- Use of tricycles or bicycle trailers for improved local transport

- Zero Energy Cool Chamber (brick and sand, 100 kg capacity) for temporary cool storage
- Small-scale cooking banana processing methods (improved solar drying, hygienic processing and packaging of green banana flour)

Figure 14: Example of a simple trailer for a bicycle (Instructables.com)

4) Postharvest agri-business opportunities for cooking bananas should be promoted.
These include:

- Trader/grower partnerships, where improved banana production, harvest practices and postharvest handling on the farm leads to increased profits for both the growers and the traders.
- Manufacture and sales of improved small-scale transport (tricycles, bicycle trailers, cargo bikes, etc.)
- Local manufacture of cooking banana flour (with flavors/dried vegetable mixes, package sizes, types and prices targeted to local consumer preferences).

5. LIFE CYCLE ASSESSMENT

Methodology

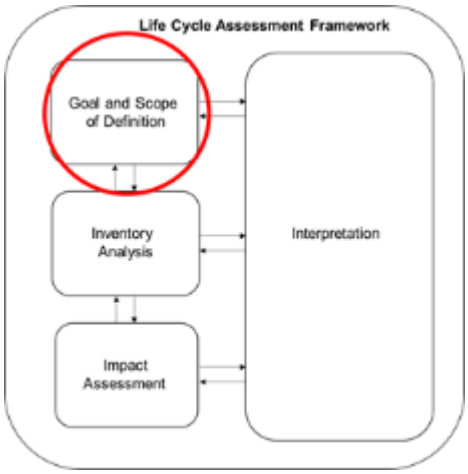
Postharvest loss occur across the value chain for all crops in all economies, however, in Rwanda there are particularly high postharvest losses. These losses directly reduce the final yield of the saleable and consumable product. Reduced product yield translates to more land, water, fertilizers, chemicals, and other inputs per kg or mass of final product sold to a consumer. Reducing postharvest losses is key to reducing the environmental impacts of agriculture products and conserving the limited resources in Rwanda.

The spoiling of food creates environmental impacts in multiple ways. First, the resources and energy required to make food is greatly increased on a per pound consumed basis when much of the food fails to successfully reach the market. To maximize farm resource use efficiency, decreasing postharvest waste is the largest environmental lever. In addition to increasing the efficiency of our resource use on the farm level, by decreasing food waste, the energy and resources used to bring the food to market will not be wasted on spoiled food. Furthermore, wastes associated with spoiled food will be reduced which lowers the environmental impacts of decomposing food and resources required to dispose of this food waste. Environmental sustainability analysis will focus on fossil fuel use and greenhouse gas (GHG) emissions associated with the crop value chain. The environmental hotspots, or stages after harvest that create the most environmental impacts, will be identified. GHG emission and energy use associated with new postharvest practices resulting from this work will be determined and compared to the business as usual values. This will ensure that postharvest improvements will also benefit the environment and will help ensure a sustainable and more prosperous future for the people of Rwanda.

Life Cycle Assessment Overview

Life cycle assessment (LCA) is a standardized procedure used to determine the environmental impacts of products services or goods. The standardized procedure can be described by four-part framework as outlined by the 14044 ISO standard which includes:

1. Goal and scope definition
2. Life cycle inventory
3. Life cycle impact assessment
4. Interpretation



This integrated framework was inspired by earlier forms of life cycle thinking originating in life cycle financial analysis. Examining a product from origination of materials, to use and disposal provides more holistic analysis of systems that can identify where environmental impacts originate and guide efforts in reducing these impacts.

The ISO standards provides guidance on the structure framework, reuses requirements of data, study assumptions, and methods. With more consistent LCA methodologies, studies can be more comparable and of more scientific rigor. A standardized method helps LCA practitioners manage complex datasets consistently, enable comparisons between different products, and allow benchmarking. Without a standardized method, the results of LCA studies would be even more variable depending on study assumptions and methods. The ISO standards help reduce the influence of practitioner influence on study results.

A brief description of the four steps is provided below before presenting an in depth description of each process in the following section.

Goal and scope definition:
The assumptions surrounding an LCA study can heavily influence the analysis results and conclusion. There are many different types of studies requiring different levels data collection and analysis. The goal and scope of a LCA defines the purpose, audience, and intended use of the study. The intended use guides the further decisions surrounding scope, functional unit of comparison, and data collection methods. For instance, if a LCA study is to be used for internally within a company, a full review panel of LCA experts is not required, however, when making publically facing environmental claims about a competing product, this review is required.

Inventory analysis
The life cycle inventory (LCI) represents the most laborious step of a LCA where data is collected and organized for further analysis. This step often involves contacting companies, literature review, and building models in life cycle assessment software. Material flows in and out of processes, types of materials, product life time, and product energy requirements are examples of data typically collected in the LCI phase.

Life Cycle Impact Assessment
The life cycle impact assessment (LCIA) step of the analysis process takes life cycle inventory data and computes values that represent some form of environmental impacts. This process simplifies the data set from hundreds of flows into 10 or less impact categories that can then be

use for decision making. There are many different methods for LCIA based on location, goal and scope of the study.

Interpretation

The interpretation step of LCA reflects on what was found in the other steps to create new knowledge. It should be noted that the interpretation step is not the last step, rather it is continually done throughout each process. When this is done in each stage, study assumptions, goals and scopes, and methods are often refined to create to better suit the needs of the study commissioner.

Integrated Post Harvest Supply Chain Analysis and Life Cycle Assessment Approach

The environmental analysis leverages a framework called Life Cycle Assessment (LCA) that is used to quantify the material inputs and outputs and quantify the environmental impacts of resource use and emissions to the environment. Postharvest solutions analyzed through the lenses of life cycle assessment offers a new approach to identify inefficiencies and determining key leverage points where changes made can create the most positive benefits.

Postharvest losses occur across the value chain for all crops in all economies, however, in Rwanda there are particularly high postharvest losses. These losses directly reduce the final yield of the saleable and consumable product. Reduced product yield translates to more land, water, fertilizers, chemicals, and other inputs per kg or mass of final product sold to a consumer. The LCA framework can quantify the wasted resources and land resulting prom post harvest losses. Reducing postharvest losses is key to reducing the environmental impacts of agriculture products and conserving the limited resources in Rwanda.

Environmental sustainability analysis will focus on fossil fuel use and greenhouse gas (GHG) emissions associated with the crop value chain. The environmental hotspots, or stages after harvest that create the most environmental impacts, will be identified. GHG emission and energy use associated with new postharvest practices resulting from this work will be determined and compared to the business as usual values. This will ensure that postharvest improvements will also benefit the environment and will help ensure a sustainable and more prosperous future for the people of Rwanda.

System boundary

The system boundary for an LCA defines what is and what is not included within an analysis. Processes or stages of a product's life cycle within the dashed line is included in the analysis while aspects outside the dashed lines are omitted in the analysis. In the case of green bananas, this study focuses on the growing, processing, transportation and wholesale trading.

Retail markets and regional markets are outside of the system boundary.

Functional unit

The functional unit of a LCA defines the quantity or measure of service for which an analysis is based. In this postharvest analysis, the functional unit is defined as 1 delivered tonne of product. This functional unit includes losses along the postharvest supply chain that occur to deliver one tonne of product. Data Collection. In this analysis, IPCC 2013 GHG impact assessment method was used.

Primary data

Data was collected from growers and areas within the postharvest supply chain through interviews and surveys. Data collected for the LCA was supplemented with data from the modified Commodity System Analysis Method (CSAM) assessment under the same funding source. Data from the CSAM assessment included postharvest losses, transportation distances, and other farming practices.

Secondary data

Secondary datasets used developed from two different sources including literature and existing LCA databases. Country data describing crop yields, planted area, and fertilization rates were collected from literature sources and Rwandan government documents. In addition to those sources, LCA databases were used including United States Life Cycle Inventory (USLCI) database and the Ecoinvent database.

Study Limitations

Primary data collected and presented herein describing agriculture production in Rwanda has limitations do to small samples sizes. To account for small sample sizes, literature and other data sources were also used and compared to the collected data. Much of the life cycle inventory analysis data is based on world average impact data for each of the studies crops. There will be significant differences between the world average crop impacts and the impacts resulting from Rwandan agriculture practices, however, the use of world average provides a starting point for further analysis and helps identify hotspots.

Findings

Greenhouse Gas hotspots

Using LCA data representing a world average banana data production with irrigation activities removed, there are several main GHG hotspots that carry the majority of the environmental

burdens, Figure 13. The fertilizer production and use represent 29% and 52% of total GHG emissions, respectively. When combined, they account for 81% of the total GHG emissions associated with global banana production. In the original dataset describing the world average banana production, irrigation GHG emissions were nearly half of the total, however, in Rwanda, banana farms are rarely irrigated, thus was removed. The total emission per tonne of banana produced is 144 kg CO_2 per tonne, before post harvest losses.

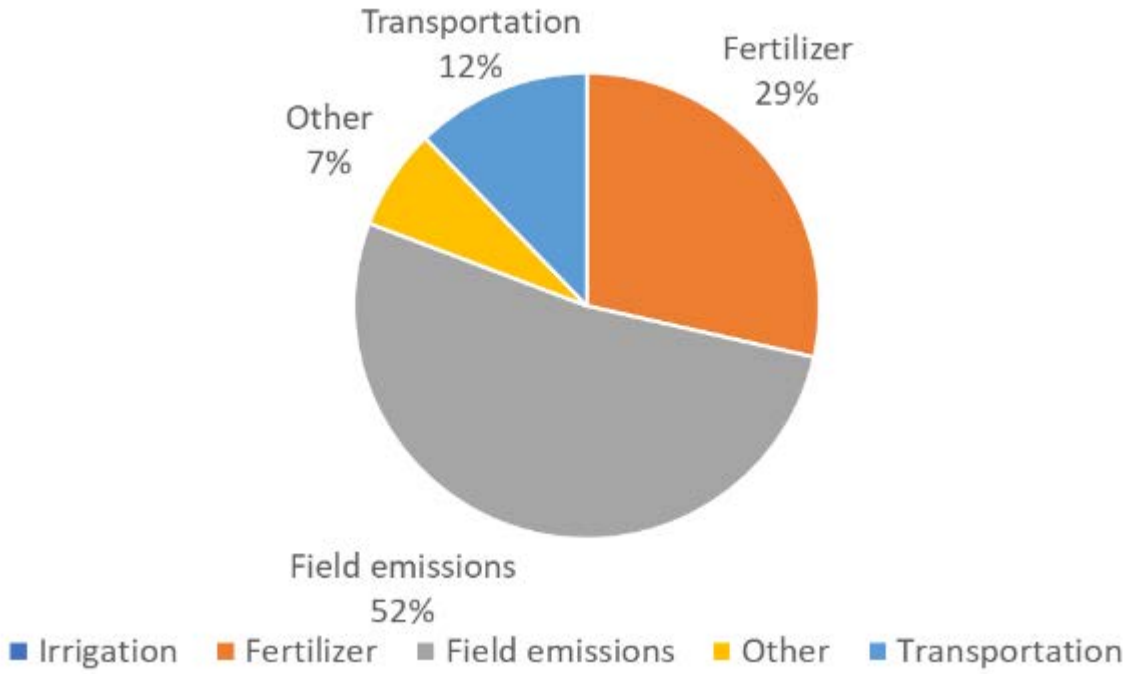


Figure 15: World average banana production GHG hotspots

Unlike the other crops, global banana production used more animal manure, 43.5 kg per tonne banana, Table 11. In addition to animal fertilizers, synthetic fertilizers were also reportedly used and contribute highly to the overall GHG emissions.

Table 11: Global average banana fertilizer use in kg per tonne

Fertilizer	kg/tonne
Ammonia nitrate and other forms of N, as N	3.1
Animal fertilizer	43.5
Potassium sulfate, as K2O	3.5

Irrigation

Irrigation data using the world average banana data, 343 cubic meters of irrigation water are

consumed per tonne of banana production. In Rwanda, banana crops are rarely irrigated as the rainy season provides the enough water to grow reasonable yields. Since no irrigation water is consumed, there is little to no impact on water supplies and availability.

Impacts of Postharvest Losses

The cooking bananas were reported to be highly damaged and decayed which decreases crop value, however, very small amounts of bananas are discarded. Since the CSAM assessment did not quantify the quantity that is discarded (as sorting out is very low), the savings due to increased produce use cannot be determined and would be minimal.

Recommendations

Fertilizer application

The grower interviews provided key data used in this analysis as well as insights into ways in which growing practices can be changed to decrease resource use and environmental impacts. As identified earlier in this report, fertilizers are a major contributor to greenhouse gasses and consume large amounts of energy during production. Additionally, though not quantified herein, they contribute to nutrient loading and can cause water quality issues. Despite this there are major benefits of fertilizer use that must be balanced against the impacts and where fertilizers are used, they should be used effectively.

Future Work

The environmental data used in this work is derived from both literature and grower interviews. In future efforts, more grower interviews would help provide a more representative dataset describing agriculture systems. In addition to a larger set of grower interviews, the grower practices should be delineated into different types of systems such as irrigated, swamp grown, and non-irrigated. Data characterizing these different growing regions would be helpful to gain a more comprehensive understanding of all the major growing practices and their environmental impacts.

References

Affognon et al. Unpacking postharvest losses in Sub-Saharan Africa: A Meta-analysis World Development Vol. 66, pp. 49–68, 2015.

Brentrup, Frank; Yara International ASA, 2014. *Energy efficiency and greenhouse gas emissions in European nitrogen fertilizer production and use V9,* Research Centre Hanninghof, Hanninghof 35, D-48249 Dülmen, Germany. http://www.fertilizerseurope.com/fileadmin/user_upload/publications/agriculture_publications/Energy_Efficiency__V9.pdf

Boulay, A.M., et al. Submitted to International Journal of Life Cycle Assessment 2016.

CIALCA Project Survey Report, Banana Marketing in Rwanda, Burundi and South Kivu, 2005

Clay, D. and Turatsinze, J. 2014. Baseline Report on the Rwanda Horticulture Organisations Survey, Rawanda Ministry of Agriculture and Animal Resources (MINAGRI).

EU. 2015. Baseline Report on the Rwanda Horticulture Organization Survey Final Report. European Union External Cooperation Program for Rwanda. March 2014

Fertilizers Europe, 2016. Carbon Footprint Reference Values, Energy efficiency and greenhouse gas emissions in European mineral fertilizer production and use.

Hoekstra, A. Y. (2016). A critique on the water-scarcity weighted water footprint in LCA. Ecological indicators, 66, 564-573.

Hoekstra, A. Y., & Chapagain, A. K. (2006). Water footprints of nations: water use by people as a function of their consumption pattern. In *Integrated Assessment of Water Resources and Global Change* (pp. 35-48). Springer Netherlands.

Joel Mpawenimana, Analysis of Socio-Economic Factors Affecting the Production of Bananas in Rwanda, University of Nairobi, 2012

JE Austin 2009. Study on Market, Post Harvest and Trade Opportunities for Fruits and Vegetables in Rwanda

Joas, J. and M. L´echaudel, “A comprehensive integrated approach for more effective control of tropical fruit quality,” Stewart Postharvest Review, vol. 4, no. 2, pp. 1–14, 2008.

Kilimo Trust, Banana Value Chains in East Africa: Consumption, Productivity and Challenges, 2010

Kitinoja, L. 2013. Use of cold chains for reducing food losses in developing countries. White Paper No. 13-03. La Pine, Oregon USA: The Postharvest Education Foundation. 16pp http://postharvest.org/Use%20of%20cold%20chains%20PEF%20white%20paper%2013-03%20final.pdf

Kitinoja, L. 2013. Returnable Plastic Crate (RPC) systems can reduce postharvest losses and improve earnings for fresh produce operations. White Paper No. 13-01. La Pine, Oregon USA: The Postharvest Education Foundation. 26pp. http://postharvest.org/RPCs%20PEF%202013%20White%20paper%2013-01%20pdf%20final.pdf

Kitinoja, L. and Kader A.A. (2015). Measuring fruit and vegetable losses in developing countries. PEF White Paper No. 15-01. La Pine, Oregon USA: The Postharvest Education Foundation. 26pp

Kitinoja, L. and AlHassan, H. A. (2012). Identification of Appropriate Postharvest Technologies for Improving Market Access and Incomes for Small Horticultural Farmers in Sub-Saharan Africa and South Asia. Part 1: Postharvest Losses and Quality Assessments. Acta Hort (IHC 2010) 934: 31-40.

Kitinoja, L. and Thompson J F, (2010). Pre-cooling systems for small-scale producers. Stewart Postharvest Review 2010, **6**(2):1-14

LaGra, J., Kitinoja L. and K. Alpizar (2016). Commodity Systems Assessment Methodology for Value Chain Problem and Project Identification: A first step in food loss reduction. San Jose, Costa Rica: IICA. 246 pp. http://repiica.iica.int/docs/B4232i/B4232i.pdf

Malesu M. M., Oduor A.R., Chrogony K., Nyolei D., Gachene C.K.K., Biamah E. K., O’Neil M., Ilyama M. and Mogoi J. 2010. Rwanda Irrigation Master Plan. The Government of Rwanda, Ministry of Agriculture and Animal Resources, Ebony Company Limited and World Agroforestry Centre (ICRAF). Nairobi, Kenya. 240p +xii p; includes bibliography.

MPRA. 2010. Value Chain Analysis of Paprika and BEC in Malawi

NAEB. Leading Horticulture Companies in Rwanda. http://www.naeb.gov.rw/fileadmin/documents/LEADING_HORTICULTURE_COMPANIES_IN_RWANDA.pdf

One Acre Fund, Bananas in Rwanda, 2014

Saran, S., Roy, S. K. and Kitinoja, L. (2012). Appropriate Postharvest Technologies for Improving Market Access and Incomes for Small Horticultural Farmers in Sub- Saharan Africa and South Asia. Part 2: Field Trial Results and Identification of Research Needs for Selected Crops. Acta Hort (IHC 2010) 934: 41-52.

Toivonen, P. M. A. "Fruit maturation and ripening and their relationship to quality," *Stewart Postharvest Review*, vol. 3, no.2, 5 pages, 2007.

University of KwaZulu Natal. Banana Cultivar Distribution in Rwanda, Research Center for Plant Growth and Development, 2008

WBCSD, World Resources Institute, 2015. GHG Protocol Agricultural Guidance, Interpreting the corporate accounting and reporting standard for agriculture sector.

Winrock International, (2009). Empowering agriculture: Energy options for horticulture. US Agency for International Development 79 pp.

WFLO (2010) Appropriate Postharvest Technologies for Improving Market Access and Incomes for Small Horticultural Farmers in Sub- Saharan Africa and South Asia. WFLO project final report for the Bill and Melinda Gates Foundation. 318 pp.

Annexes

Annex 1: CSAM Questionnaires and worksheets

ANNEX 1A: CSAM SUMMARY QUESTIONS LIST

Crop value chain assessment for the Reducing Postharvest Losses in Rwanda project.

CROP # 1 _____

Components 1 - 7: Pre-Production

(Date sources include extension workers, researchers, project partners)

1- Importance of the crop. What is the relative importance of the crop? Base your estimate of importance on information on number of producers, amount produced, area of production, and/or market value.

2- Governmental policies. Are there any laws, regulations, incentives or disincentives related to producing or marketing the crop? (e.g., existing price supports or controls, banned pesticides or residue limits)

3- Relevant institutions. Are there any organizations involved in projects related to production or marketing the crop? What are the goals of the projects? How many people are participating?

4- Facilitating services. What services are available to producers and marketers (for example: credit, inputs, technical advice, subsidies)?

5- Producer/shipper organizations. Are there any producer or marketer organizations involved with the crop? What benefits or services do they provide to participants? At what cost?

6- Environmental conditions. Does the local climate, soils or other factors limit the quality of production? Are the cultivars produced appropriate for the location?

7- Availability of planting materials. Are seeds or planting materials of adequate quality? Can growers obtain adequate supplies when needed?

Components 8 - 11: Production (Data sources include farmers, extension workers, project staff)

8- Farmers' general cultural practices. Do any farming practices in use have an effect on produce quality (irrigation, weed control, fertilization practices, field sanitation)?

9- Pests and diseases. Are there any insects, fungi, bacteria, weeds or other pests present that affect the quality of produce?

10- Pre-harvest treatments. What kinds of pre-harvest treatments might affect postharvest quality (such as use of pesticides, pruning practices, trellising, thinning)?

11- Production costs. What are the costs of any proposed alternative methods?

Components 12 - 21: Postharvest
(Data sources include farmers, extension workers, marketers, processors, project partners)
12- Harvest. When and how is produce harvested? by whom? at what time of day? Why? What sort of containers are used? (if possible, take photos). Is the produce harvested at the proper maturity for the intended market? What is the temperature at harvest time? What amounts and types of losses are observed/reported?
13- Grading, sorting and inspection. How is produce sorted? by whom? Does value (price) change as quality/size grades change? Do local, regional or national standards (voluntary or mandatory) exist for inspection? What amounts and types of losses are observed/reported? What happens to culled produce?
14- Postharvest treatments. What kinds of postharvest treatments are used? (Describe any curing practices, cleaning, trimming, hot water dips, etc.) Are treatments appropriate for the product? (if possible, take photos).
15- Packaging. How is produced packed for transport and storage? What kind of packages are used? Are packages appropriate for the product? Can they be reused or recycled? (if possible, take photos).
16- Cooling (if any). When and how is produce cooled? To what temperature? Using which method(s)? If temperature measured during cooling? Are methods appropriate for the product? If produce is not cooled. What is the ambient temperature range during the postharvest period?
17- Storage (if any). Where and for how long is produce stored? In what type of storage facility? Under what conditions (packaging, temperature, RH, physical setting, hygiene, inspections, etc.)? Is the temperature measured while the produce is in storage? (if possible, take photos).
18- Transport. How and for what distance is produce transported? In what type of vehicle? How many times is produce transported? How is produce loaded and unloaded? (if possible, take photos).
19- Delays/ waiting. Are there any delays during handling? How long and under what conditions (temperature, RH, physical setting) does produce wait between steps?
20- Other handling. What other types of handling does the produce undergo? Is there sufficient labor available? Is the labor force well trained for proper handling from harvest through transport? Would alternative handling methods reduce losses? Would these methods require new workers or displace current workers?
21- Agro-processing (if any). How is produce processed (methods, processing steps) and to what kinds of products? How much value is added? Are sufficient facilities, equipment, fuel, packaging materials and labor available for processing? Is there consumer demand for processed products?

Components 22 - 26: Marketing

(Data sources include farmers, traders, wholesale marketers, retail marketers, consumers, extension workers, project partners)

22- Market intermediaries. Who are the handlers of the crop between producers and consumers? How long do they have control of produce and how do they handle it? What amounts and types of losses are observed/reported? Who is responsible for losses /who suffers financially? Is produce handled on consignment; marketed via direct sales; move through wholesalers?

23- Market information. Do handlers and marketers have access to current prices and volumes in order to plan their marketing strategies? Who does the recordkeeping? Is information accurate, reliable, timely, and useful to decision makers?

24- Consumer demand. Do consumers have specific preferences for produce sizes, flavors, colors, maturities, quality grades, packages types, package sizes or other characteristics? Are there any signs of unmet demand and/or over-supply? How do consumers react to the use of postharvest treatments (pesticides, irradiation, coatings, etc.) or certain packaging methods (plastic, Styrofoam, recyclables)?

25- Exports. Is this commodity produced for export? What are the specific requirements for export (regulations of importing country with respect to grades, packaging, pest control, etc.)?

26- Marketing costs. Do handlers/ marketers have access to credit? Are prevailing market interest rates at a level that allows the borrower to repay the loan and still make a profit? Is supporting infrastructure adequate (roads, marketing facilities, management skills of staff, communication systems such as telephone, FAX, e-mail services)? What are the costs of any proposed change in marketing practices?

ANNEX 1B: ON FARM DATA COLLECTION WORKSHEET

ON FARM DATA COLLECTION WORKSHEET Name of Data Collector:

PLANTAINS Variety (if known _____) or describe color, shape, etc

Code: Farm_____

Questions and observations	At Harvest		Farm gate	
Date				
Location of farm				
Size of farm				
Crops produced				
Season of plantains (range of harvest dates on this farm)				
Name of destination market if known				
Distance to market if known	_____km		Expected journey time _____hours	
Sorting - selecting out that produce which will not be sent to the market	Was sorting done at harvest? Yes/No	If Yes, estimate waste (discarded) _____% or left in the field _____% Reason for sorting out:	Was sorting done before farm gate sale? Yes/No	If Yes, estimate waste (discarded):_____% Reason for sorting out:
Size Grading : is there any grading into different sizes on the farm?	If Yes, estimate % in each category: Large ____% ; Medium ____% ; Small ____%		If Yes, estimate % in each category: Large _____% ; Medium ____% ; Small ____%	
Does price offered vary by quality grade?	Describe grading criteria:		If Yes, what is the price offered for each quality grade? Highest _____ ; Middle _____ ; Lowest _____	
Expected farm gate price:			Price offered _____ (by weight? By Volume? By Number of containers?) Price per kg: _____	
MEASUREMENTS	**At Harvest**		**Farm gate (to be measured again if possible)**	
Sample size (select random samples)	count of 20		count of 20	
Time from harvest	0 hour			
Time of day				
Air temperature	_____ C		_____ C	
Relative humidity indicator	Wet bulb T: _____ Dry bulb T : _____		Wet bulb T: _____ Dry bulb T : _____	
Pulp temperature in °C (3 randomly selected fruits)				
Quality sort for defects, decay, damage (# out of count of 20) Ratings from 5= Extreme defects, decay or damage; 3 = moderate; 1 = none	Number of rating 5 _____ Number of rating 3 _____ Number of rating 1 _____		Number of rating 5 _____ Number of rating 3 _____ Number of rating 1 _____	
number with obvious defects ie: cracks, sunburn, misshapen, etc				

PLANTAINS Worksheet
Code: Farm_____

	Harvest	Farm gate (to be measured again if possible)
Describe defects found (take photos)		
number with decay symptoms		
Describe decay found (take photos)		
number damaged ie: bruises, cuts, mechanical injury, insect damage		
Describe damages found (take photos)		
Ripeness rating: 5=full color, full ripe 4= light yellow 3= yellowish green 2= light green 1= dark green	Number full color _____ ____ light yellow ____ yellowish green ____ light green ____dark green	Number full color _____ ____ light yellow ____ yellowish green ____ light green ____dark green
Firmness (measure 3 randomly selected fruits)		Finger pressure test where 5= fruit is hard, yields only slightly to firm pressure 3 = is firm 1= fruit is very soft, yields readily to slight pressure
Rate package protection	____5 = very strong, protective ____4 = strong, moderately protective ____3 = somewhat strong, protective ____2 = weak, not very protective ____1 = no pkg or very weak, no	____5 = very strong, protective ____4 = strong, moderately protective ____3 = somewhat strong, protective ____2 = weak, not very protective ____1 = no pkg or very weak, no protection
Describe package or container: **Type, material, dimensions, cooling efficiency, etc**		
Size and/ or weight of package or container		
Weight loss on farm (set aside an initial random sample, weigh it again at time of sale)	Initial weight of sample	Weight at time of sale

% are calculated by #/20 or weight/total weight of sample or count/total count of sample

PLANTAINS Worksheet
Code: Farm_____

ANNEX 1C: WHOLESALE DATA COLLECTION WORKSHEET

WHOLESALE DATA COLLECTION WORKSHEET Name of Data Collector:

PLANTAINS Variety (if known _____) or describe color, shape, etc

Code: WhSale_____

Questions and observations	on Arrival		at time of sale	
Date				
Name of market				
Location of market				
Season of plantains (range of sales dates at this market))				
Distance from farm if known	_____km			
Sorting - selecting out that produce which will not be resold	Was sorting done before delivery? Yes/No	If Yes, estimate waste (discarded) _____% Reason for sorting out:	Was sorting done before sale? Yes/No	If Yes, estimate waste (discarded):_____% Reason for sorting out:
Size Grading : is there any grading into different sizes at the market?	If Yes, estimate % in each category: Large ____% ; Medium ____% ; Small ____%		If Yes, estimate % in each category: Large _____% ; Medium ____% ; Small ____%	
Does price offered vary by quality grade?	Describe grading criteria:		If Yes, what is the price offered for each quality grade? Highest _____ ; Middle _____ ; Lowest _____	
Expected wholesale price:			Price range _____ (by weight? By Volume? By Number of containers?) Price per kg: _____	
MEASUREMENTS	**on arrival**		**at time of sale (if possible to measure)**	
Sample size (select random samples)	count of 20		count of 20	
Time from harvest if known				
Time of day				
Air temperature	_____ C		_____ C	
Relative humidity indicator	Wet bulb T: _____ Dry bulb T : _____		Wet bulb T: _____ Dry bulb T : _____	
Pulp temperature in °C (3 randomly selected fruits)				
Quality sort for defects, decay, damage (# out of count of 20) Ratings from 5= Extreme defects, decay or damage; 3 = moderate; 1 = none	Number of rating 5 _____ Number of rating 3 _____ Number of rating 1 _____		Number of rating 5 _____ Number of rating 3 _____ Number of rating 1 _____	
number with obvious defects ie: cracks, sunburn, misshapen, etc				
	on arrival		**at time of sale**	
Describe defects found (take photos)				

PLANTAINS Worksheet
Code: WhSale_____

number with decay symptoms		
Describe decay found (take photos)		
number damaged ie: bruises, cuts, mechanical injury, insect damage		
Describe damages found (take photos)		
Ripeness rating: 5=full color, full ripe 4= light yellow 3= yellowish green 2= light green 1= dark green	Number full color _____ ____ light yellow ____ yellowish green ____ light green ____dark green	Number full color _____ ____ light yellow ____ yellowish green ____ light green ____dark green
Firmness (measure 3 randomly selected fruits)		Finger pressure test where 5= fruit is hard, yields only slightly to firm pressure 3 = is firm 1= fruit is very soft, yields readily to slight pressure
Rate package protection	____5 = very strong, protective ____4 = strong, moderately protective ____3 = somewhat strong, protective ____2 = weak, not very protective ____1 = no pkg or very weak, no	____5 = very strong, protective ____4 = strong, moderately protective ____3 = somewhat strong, protective ____2 = weak, not very protective ____1 = no pkg or very weak, no protection
Describe package or container: **Type, material, dimensions, cooling efficiency, etc**		
Size and/ or weight of package or container		
Weight loss (set aside an initial random sample, weigh it again at time of sale)	Initial weight of sample	Weight at time of sale

% are calculated by #/20 or weight/total weight of sample or count/total count of sample

PLANTAINS Worksheet
Code: WhSale_____

Annex 1 D: RETAIL DATA COLLECTION WORKSHEET

RETAIL DATA COLLECTION WORKSHEET Name of Data Collector:

PLANTAINS Variety (if known _____) or describe color, shape, etc

Code: Retail_____

Questions and observations	on Arrival		6 to 8 hours later	
Date				
Name of market				
Location of market				
Season of plantains (range of sales dates at this market))				
Distance from farm if known	_____km			
Sorting - selecting out that produce which will not be resold	Was sorting done before delivery? Yes/No	If Yes, estimate waste (discarded) _____% Reason for sorting out:	Was sorting done before sale? Yes/No	If Yes, estimate waste (discarded):_____% Reason for sorting out:
Size Grading : is there any grading into different sizes at the market?	If Yes, estimate % in each category: Large ____% ; Medium ____% ; Small ____%		If Yes, estimate % in each category: Large _____% ; Medium ____% ; Small ____%	
Does price offered vary by quality grade?	Describe grading criteria:		If Yes, what is the price offered for each quality grade? Highest _____ ; Middle _____ ; Lowest _____	
Expected retail price:			Price range _____ (by weight? By Volume? By Number ?) Price per kg: _____	
MEASUREMENTS	**on arrival**		6 to 8 hours later	
Sample size (select random samples)	count of 20		count of 20	
Time from harvest if known				
Time of day				
Air temperature	_____ C		_____ C	
Relative humidity indicator	Wet bulb T: _____ Dry bulb T : _____		Wet bulb T: _____ Dry bulb T : _____	
Pulp temperature in °C (3 randomly selected fruits)				
Quality sort for defects, decay, damage (# out of count of 20) Ratings from 5= Extreme defects, decay or damage; 3 = moderate; 1 = none	Number of rating 5 _____ Number of rating 3 _____ Number of rating 1 _____		Number of rating 5 _____ Number of rating 3 _____ Number of rating 1 _____	
number with obvious defects ie: cracks, sunburn, misshapen, etc				
	on arrival		6 to 8 hours later	
Describe defects found (take photos)				

Plantains Retail Worksheet
Code: Retail_____

number with decay symptoms		
Describe decay found (take photos)		
number damaged ie: bruises, cuts, mechanical injury, insect damage		
Describe damages found (take photos)		
Ripeness rating: 5=full color, full ripe 4= light yellow 3= yellowish green 2= light green 1= dark green	Number full color _____ ____ light yellow ____ yellowish green ____ light green ____dark green	Number full color _____ ____ light yellow ____ yellowish green ____ light green ____dark green
Firmness (measure 3 randomly selected fruits)		Finger pressure test where 5= fruit is hard, yields only slightly to firm pressure 3 = is firm 1= fruit is very soft, yields readily to slight pressure
Rate package protection	____5 = very strong, protective ____4 = strong, moderately protective ____3 = somewhat strong, protective ____2 = weak, not very protective ____1 = no pkg or very weak, no	____5 = very strong, protective ____4 = strong, moderately protective ____3 = somewhat strong, protective ____2 = weak, not very protective ____1 = no pkg or very weak, no protection
Describe package or container: **Type, material, dimensions, cooling efficiency, etc**		
Size and/ or weight of package or container		
Weight loss (set aside an initial random sample, weigh it again 6 to 8 hours later)	Initial weight of sample	Weight at 6 to 8 hours later

% are calculated by #/20 or weight/total weight of sample or count/total count of sample

Plantains Retail Worksheet
Code: Retail_____

Annex 1E: Cost/Benefit worksheet

Costs and Benefits Worksheet

For any observed IMPROVED postharvest handling technology or practice:
Assume harvest 1000 kg

Crop_____ Country: Rwanda Region_____

	Current Practice	New Practice
Describe:		
COSTS		
Relative cost		
EXPECTED BENEFITS		
% losses		
Amount for sale		
Value/kg		
Total market value		
Market value minus costs		
Relative profit		
ROI		

Annex 1F: Data Collection Protocol

HOW TO USE THE POSTHARVEST DATA COLLECTION WORKSHEETS

SITE SELECTION:
The project will cover the traditional domestic marketing value chains. Cooking bananas and the sites where it is grown are chosen because goes into the typical domestic wholesale market chain and not to export or supermarkets.
The individual sheets are code numbered (Bananas Farm01, Bananas Whsale02, etc up to 10 complete sets of data at the farm, wholesale market and retail market.
It is useful to ask questions to the farmer will know what happens between harvest and the farm gate, the wholesaler will be able to tell what happens between purchase and resale, etc.

Measurements
Averages will be calculated via computer once all the raw data (the actual readings or measurements) is submitted.

FARM
The data is collected during harvest at the farm gate.
The change in weight is the information of highest interest, one random sample of 20 fruits is put aside and the weigh is taken at harvest and again at farm gate.

WHOLESALE MARKET
Purchase the produce from the wholesale market at the time of arrival, do our measurements and then hold our sample until the lot is sold (and take the readings again) keeping the sample in similar conditions to the lot that is being sold (ex: exposed to the sun).

RETAIL MARKET
Collect data only at open street style markets. If we try to add shops, supermarkets, export markets, etc, we will have too little data from these diverse markets to make any conclusions. Retails samples of 20 randomly selected items of produce will need to be purchased from the vendor.

PACKAGE:
<u>Protection</u>
The package protection strength is evaluated as
- 5=very strong, protective
- 4= strong, moderately protective

- 3=somewhat strong, somewhat protective
- 2=weak, not very protective
- 1=no package or very weak, offering no protection

Description of package or container

- Type
- material
- dimensions
- cooling efficiency

TAKE PHOTOS: Photos are good indicators of visual defects, maturity or quality rating scales. Photos of defects or damages, should be labeled using the same code as the worksheet plus a descriptive name (ex: Bananas Farm 01 damage1, Bananas Whsale 02 decay1, etc)

ANNEX 2: LIST OF TOOLS FOR THE FIELD

- The Oseri Pronto digital scale operates on 2 AAA batteries, has a capacity of 1.0 gram to 5,050 grams, with a tare feature. It weighs 300 grams and measures 8.2 x 1.8 x 6 inches and comes with a one-year warranty. It has received a 4.5 star Amazon rating (5.0 max) from 9,669 purchasers.
- The Camry Luggage Scale has a capacity of 50 kg, and is suitable for weighing crates of produce. It has a tare function and operates on one 3v lithium battery cell CR2032. It weighs 7180 grams. It has received a 4.5 star Amazon rating (5.0 max) from 283 purchasers.
- The Taylor Precision Waterproof Digital Thermometer Probe:with a range of -40 to 230 Celsius. It has a hold feature, allowing remote readings, and is fully waterproof. It is a pen-style instrument with a lanyard for easy field use. It has received a 4.0 star Amazon rating (5.0 max) from 9,669 purchasers.
- Tools for measuring wet bulb T using the digital thermometer probe: (for RH calculations): 10 cm of cotton gauze, tie to bind gauze to T. probe, water to saturate gauze, psychometric chart and instructions for how to use
- BANANA RIPENESS CHART (UC DAVIS)

Annex 3: LIST OF INTERVIEWEES

DATE	LOCATION	NAME	AFFILIATION	PURPOSE
19-Jan-17	Nyabugogo Market	Murindabigwi Eric	Green Banana Trader	CSA Questionnaire interview
19-Jan-17	Kimironko Market	Nyiranshuti Jeanne D'Arc	Green Banana Trader	CSA Questionnaire interview
19-Jan-17	Kimironko Market	Kwitonda Robin	Green Banana Transporter (Rusizi-Kigali)	CSA Questionnaire interview
19-Jan-17	Kimironko Market	Mwitirehe Daphose	Green Banana wholesaler	CSA Questionnaire interview and data collection
19-Jan-17	Kimironko Market	Nzeyimana Jean Claude	Green Banana wholesaler	CSA Questionnaire interview and data collection
19-Jan-11	Nyabugogo Market	Karangwa	Green Banana wholesaler	CSA Questionnaire interview and data collection
20-Jan-17	Kimsagara Market	Nsekanabo Narcisse	Green Banana Wholesaler	CSA Questionnaire interview and data collection
20-Jan-17	Nyabugogo Market	Hakizumwami Pierre	Green Banana Wholesaler	CSA Questionnaire interview and data collection
20-Jan-17	Kimisagara Market	Mukundehe Emertha	Green banana Retailer	CSA Questionnaire interview and data collection
20-Jan-17	Kimisagara Market	Bizimana Jean Claude	Green banana Retailer	CSA Questionnaire interview and data collection
20-Jan-17	Nyamirambo Market	Kavakure Hamisi	Green banana Retailer	CSA Questionnaire interview and data collection
20-Jan-17	Nyamirambo Market	Twizeyimana Eric	Green banana Retailer	CSA Questionnaire interview and data collection
20-Jan-17	Nyamirambo Market	Murera Jean Nepomscene	Green banana Retailer	CSA Questionnaire interview and data collection
2-	Rwamagana	Munyamasoko	Green banana farmer	CSA Questionnaire

Feb-17	District	Celestin		interview and data collection
2-Feb-17	Rwamagana District	Twagirayezu Faustin	Green banana farmer	CSA Questionnaire interview and data collection
2-Feb-17	Rwamagana District	Harerimana Leonidas	Green banana farmer	CSA Questionnaire interview and data collection
14-Feb-17	Rwamagana District	Mukesha Beatrice	Green banana farmer	CSA Questionnaire interview and data collection
14-Feb-17	Rwamagana District	Mutibagirana Evarist	Green banana farmer	CSA Questionnaire interview and data collection
14-Feb-17	Rwamagana District	Bizimungu Fabien	Green banana farmer	CSA Questionnaire interview and data collection
14-Feb-17	Rwamagana District	Murwanashyaka Juvenal	Green banana farmer	CSA Questionnaire interview and data collection
15-Feb-17	Bugesera District	Munyengabe Canisius	Green banana farmer	CSA Questionnaire interview and data collection
15-Feb-17	Bugesera District	Tuyishimire Clementine	Green banana farmer	CSA Questionnaire interview and data collection
15-Feb-17	Bugesera District	Nyirigira Eugene	Green banana farmer	CSA Questionnaire interview and data collection
23-Jan 17	Gucumbi District	Rugambwa Jean Maurice	Green banana flour processor	CSA Questionnaire interview

ANNEX 4: SITES INCLUDED IN THE CSAM CROP STUDY

DISTRICTS:
Rwamagana, Bugesera, Gicumbi, Kigali

Annex 5: LCA – Questionnaires and Tables

Annex 5a: Mineral Fertiliser Carbon Footprint Reference Values

MINERAL FERTILISER CARBON FOOTPRINT REFERENCE VALUES: 2011, Fertilizers Europe, validated by European Commission methodology.

Fertiliser product	Nutrient content		GHG emissions (GWP 100 yrs: IPCC, 2007)								Energy consumption*
			Fertiliser production	Fertiliser use (soil effects)					Fertiliser production + use		Fertiliser production
			At plant gate	CO_2 from urea hydrolysis	Direct N_2O from use	Indirect N_2O via NH_3	Indirect N_2O via NO_3	CO_2 from liming and CAN	Total	Total	On-site
			kg CO_2 -eq/kg product						kg CO_2-eq/kg product	kg CO_2-eq/kg nutrient	MJ/kg product
Ammonium nitrate	AN	33.5%N	1.18	0.00	1.26	0.01	0.35	0.27	3.06	9.14	14.02
Calcium ammonium nitrate	CAN	27%N	1.00	0.00	0.89	0.01	0.28	0.20	2.40	8.88	11.78
Ammonium sulphate	AMS	26%N, 14%S	0.83	0.00	0.10	0.02	0.27	0.40	2.62	10.09	10.61
Calcium nitrate	CN	15.5%N	0.68	0.00	0.65	0.00	0.16	0.00	1.50	9.67	7.23
Ammonium sulphate	AS	21%N, 24%S	0.58	0.00	0.98	0.02	0.22	0.50	2.30	10.95	8.07
Ammonium phosphates	DAP	18%N, 46%P_2O_5	0.73	0.00	0.76	0.01	0.19	0.34	2.03	11.27	6.76
Urea	Urea	46%N	0.91	0.73	2.37	0.28	0.48	0.36	5.15	11.19	23.45
Urea ammonium nitrate	UAN	30%N	0.82	0.25	1.40	0.10	0.32	0.24	3.13	10.43	13.84
NPK 15-15-15	NPK	15%N, 15% P_2O_5 15% K_2O	0.76	0.00	0.56	0.01	0.16	0.12	1.61	10.71	7.59
Triple superphosphate	TSP	48% P_2O_5	0.26	0.00	0.00	0.00	0.00	0.01	0.27	0.56	0.16
Muriate of potash	MOP	60% K_2O	0.25	0.00	0.00	0.00	0.00	0.00	0.25	0.43	3.00

Annex 5b: LCA On Farm Data Collection Worksheet

ON FARM DATA COLLECTION WORKSHEE Name of Data Collector: _____

Code: Farm___

Crop Type			
Survey date		Harvest date	
Years growing this crop		Number of harvest per year	
Grower Demographics	Age	Gender	Education level
How many years:	Growing this crop	Farming	

Farm Data			
Location of farm (GPS)			
Size of farm (hectares)			
Yield (kg product/hectare)	Total product mass (kg)	Production area (m^2 or Hectare)	
Steepness of slope	Low (mostly flat)	Moderate	High (steep)
Soil Characteristics	Clay	Sandy	Loam
Tillage method	A. Mechanical (fuel based)	B. Human powered	C. Animal Powered
Tillage practices	A. Strip till (less than 50cm)	Strip Till (more than 50cm)	C. Full till
Fuel Type for tillage	A. Diesel	B. Petrol	C. Other
Tillage Area	Hectares	Number of times per year	

Crop Nutrients	**Type**	**How many times per harvest**	**Quantity (kg/hectare)**
Fertilizer 1			
Fertilizer 2			
Fertilizer 3			
Other nutrients (list-such as lime or CAN)			
Soil testing performed	A. yes	B. No	C. No and I don't know what that is
If no, why?	I did not have enough money to test	Not available	other: describe

Pesticides, Fungicide and herbicide	Name	Target pest or disease/How many	Quantity (kg/hectare or liters/hectare)
chemical 1			
Chemical 2			
Chemical 3			

Irrigation			
Field	Irrigated area	Shared irrigation Yes/no	
Schedule	Irrigations per week	Hours irrigated	
Pump Fuel Type	A. Diesel	B. Petrol	C. Electricity
Irrigation pump	Fuel use per irrigation		pump flow rate (m^3 per time)

Environmental Concerns

	Rank your concerns				
0 I have not heard of this	**1 not concerned**	**2 neutral**	**3 slightly concerned**	**4 concerned**	**5 very concerned**
Soil removed from farm					
Climate change					
Soil quality					
Nutrient runoff					
Water availability					
Water quality					
Smoky air (particulate)					
Land salination					
PH					
Other					

Have you noticed differences in rainy seasons over the past years?	Yes	No	N/A
Have you notice your crop yield over the past	Increas	Decre	no
Have you had sufficient access to pesticides and	Yes	No	N/A

List other notes and descriptions here

ON FARM DATA COLLECTION WORKSHEET Name of Data Collector:

PLANTAINS Variety (if known _____) or describe color, shape, etc

Code: Farm_____

Questions and observations	At Harvest		Farm gate	
Date				
Location of farm				
Size of farm				
Crops produced				
Season of plantains (range of harvest dates on this farm)				
Name of destination market if known				
Distance to market if known	_____km		Expected journey time _____hours	
Sorting - selecting out that produce which will not be sent to the market	Was sorting done at harvest? Yes/No	If Yes, estimate waste (discarded) _____% or left in the field _____% Reason for sorting out:	Was sorting done before farm gate sale? Yes/No	If Yes, estimate waste (discarded):_____% Reason for sorting out:
Size Grading : is there any grading into different sizes on the farm?	If Yes, estimate % in each category: Large ____% ; Medium ____% ; Small ____%		If Yes, estimate % in each category: Large _____% ; Medium ____% ; Small ____%	
Does price offered vary by quality grade?	Describe grading criteria:		If Yes, what is the price offered for each quality grade? Highest _____ ; Middle _____ ; Lowest _____	
Expected farm gate price:			Price offered _____ (by weight? By Volume? By Number of containers?) Price per kg: _____	
MEASUREMENTS	**At Harvest**		**Farm gate (to be measured again if possible)**	
Sample size (select random samples)	count of 20		count of 20	
Time from harvest	0 hour			
Time of day				
Air temperature	_____ C		_____ C	
Relative humidity indicator	Wet bulb T: _____ Dry bulb T : _____		Wet bulb T: _____ Dry bulb T : _____	
Pulp temperature in °C (3 randomly selected fruits)				
Quality sort for defects, decay, damage (# out of count of 20) Ratings from 5= Extreme defects, decay or damage; 3 = moderate; 1 = none	Number of rating 5 _____ Number of rating 3 _____ Number of rating 1 _____		Number of rating 5 _____ Number of rating 3 _____ Number of rating 1 _____	
number with obvious defects ie: cracks, sunburn, misshapen, etc				

PLANTAINS Worksheet
Code: Farm_____

	Harvest	Farm gate (to be measured again if possible)
Describe defects found (take photos)		
number with decay symptoms		
Describe decay found (take photos)		
number damaged ie: bruises, cuts, mechanical injury, insect damage		
Describe damages found (take photos)		
Ripeness rating: 5=full color, full ripe 4= light yellow 3= yellowish green 2= light green 1= dark green	Number full color _____ ____ light yellow ____ yellowish green ____ light green ____dark green	Number full color _____ ____ light yellow ____ yellowish green ____ light green ____dark green
Firmness (measure 3 randomly selected fruits)		Finger pressure test where 5= fruit is hard, yields only slightly to firm pressure 3 = is firm 1= fruit is very soft, yields readily to slight pressure
Rate package protection	____5 = very strong, protective ____4 = strong, moderately protective ____3 = somewhat strong, protective ____2 = weak, not very protective ____1 = no pkg or very weak, no	____5 = very strong, protective ____4 = strong, moderately protective ____3 = somewhat strong, protective ____2 = weak, not very protective ____1 = no pkg or very weak, no protection
Describe package or container: **Type, material, dimensions, cooling efficiency, etc**		
Size and/ or weight of package or container		
Weight loss on farm (set aside an initial random sample, weigh it again at time of sale)	Initial weight of sample	Weight at time of sale

% are calculated by #/20 or weight/total weight of sample or count/total count of sample

PLANTAINS Worksheet
Code: Farm_____