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POSTHARVEST LOSS ASSESSMENT OF GREEN CHILIES IN RWANDA

APRIL 30, 2018

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FEED THE FUTURE INNOVATION LAB FOR HORTICULTURE

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COVER PHOTO:

Green chilies in the farm. Photo by Jesse Daystar for the Horticulture Innovation Lab.

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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.

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

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ABBREVIATIONS & ACRONYMS

CSAM	Commodity Systems Assessment Methodology
HACCP	Hazard analysis critical control points
PEF	The Postharvest Education Foundation
PHI	Post-harvest intervals
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

Chilies are a high-value fresh export crop that is currently in its infancy as an industry in Rwanda. The chili investigation focused on the current producers for export and the current exporter, as well as investigating chilies in general (other varieties and processing) and focusing on the barriers to growth for horticulture export "pioneers".

The **main challenge of the current chili fresh export sector is that there exists only one buyer / exporter** (a classic monopsony) with a non-transparent purchase and post-harvest sorting system.

A key need for the industry to evolve is to attract other investors into fresh chili exports. Supporting these early "pioneers" should be one of the goals of the Post-Harvest Training Centers, and key recommendations include working with early horticulture pioneers, both on their strategic evolution as well as on their links and support for their suppliers.

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

Summary of postharvest losses and quality problems for the crop

Inputs	• Use of poor quality, saved seed
Farmer Knowledge	• Harvesting only once per week causes growers to supply a load of mixed maturities and overall lower grade • Rough handling causes damage and increases the rate of deterioration
Cold Storage	• There are no cold chains or cool storage facilities used for green chilies. The one charcoal cool room observed during the CSAM study was not in use. Leaving green chilies at ambient temperature for 24 hours after the harvest resulted in 13% weight loss. • Proper cool storage after harvest at the farm is one of the major limitations if proper measures are put in place between supply and demand would minimize weight losses early in the value chain

Farmer Organization	• Growers lack of bargaining power for selling their produce to the exporter, • There is a lack of transparency regarding grades and sorting/grading standards.
Processing	• Lack of processing options, little opportunity to add value.

Recommendations for Reducing Postharvest Losses

Green chilies are a relatively new horticultural crop for Rwanda, but past research has identified many appropriate handling practices and improved technologies for green birds eye chilies and many other similar types of green and red chilies. Four major recommendations are provided to guide the project.

1	**Training of trainers (capacity building) in improved practices** Leaders of cooperatives involved in production should be trained in use of high quality seed, harvest indices, planning for multiple harvests/week, gentle harvesting, use of picking bags, improved postharvest handling, sorting/grading standards, use of shade.
2	**Demonstrations that are recommended for the Postharvest Training and Services Centers on cost effective practices** for reducing postharvest losses in green chilies (and other similar chili peppers) include: ● Maturity indices, quality and shelf life ● Use of aprons/wearable harvesting bags (picking bags) ● Use of shade (various types of simple, low cost structures and portable shade such as market umbrellas) ● Management of the Charcoal cool room and Zero Energy Cool Chambers (brick and sand, 100 kg capacity) for temporary cool storage ● Small-scale green chili processing methods (solar drying, sauce making, chili oils)
3	**Postharvest agri-business opportunities for green chilies should be promoted.** These include: ● Exporter/grower partnerships, where improved green chili production, harvest practices and postharvest handling on the farm leads to increased profits for both the growers and the buyers. ● Local manufacture of dried diced green chilies, green chili paste, sauces, salsas, dried powders and oils (with flavors, package sizes and prices targeted to local consumer preferences), especially for adding value to Grade 2 or rejected produce.

2. INTRODUCTION

Data from the World Bank, Rwanda (2014) reveal that in Rwanda, agriculture is the main support of the economy and is crucial to the growth of the country and its poverty reduction. The agriculture sector accounts for 39% of gross domestic production, 80% of employment and 63% of foreign exchange earnings.

Various estimates say that up to 40% of food is lost in the postharvest stage. Green chilies are produced for export mainly in the Nyanza District. Production of all types of chilies and capsicum fruits is small, but has increased from 4,100 tonnes in 2010 to 4,500 tonnes in 2014 (FAOSTATS queries http://www.fao.org/faostat/en/#data/QC) on approximately 400 hectares in total. Yield/ha is approximately 220,600 hg/ha (last reported data is for 2014).

Importance of the crop in Rwanda

The chili sector in Rwanda comprises three main varieties: Birds Eye Chili (BEC), mostly dried and exported; Scotch Bonnet Chili (SB), exported fresh and used locally fresh or processed; and Green Chilies (GB), exported fresh with a small local market.

The export of fresh chilies (green chilies and scotch bonnet) is small and undeveloped in Rwanda. Currently there is one exporter of fresh chilies (Nature Fresh) and one potential investor (Garden Fresh). Green chilies grown for export are a very small crop in Rwanda, produced on only a small portion of the total of 400 acres reported for all types of chilies/capsicum production. Most of the producers are small-scale independent farmers or cooperatives of farmers in the Nyanza District who are contracted to supply fresh green birds eye chilies to one exporter (Nature Fresh Foods Ltd.). During Jan-March 2017, the Nyanza District was the only area where fresh green chilies were being harvested.In order to develop the industry, there is an urgent need to attract more investors into this space to build healthy competition and drive production.

NAEB has identified chilies as a priority export industry amongst vegetables. The processing of chilies in Rwanda is more developed. One dryer and exporter of birds' eye chilies has been in business for almost ten years, producing for Europe. One local company (Urwibutso in Rulindo) processes scotch bonnets into a popular hot sauce.

Chilies are generally a good smallholder crop and the number of producers involved in the overall industry is quite high; for example the leading exporter of dried BEC works with approximately 12,000 out-growers. For fresh chili exports, the numbers are much smaller; the exporter of green chilies works with less than a hundred producers. The crop is suitable for an out-grower model whereby a buyer (who also may be a producer) with market links to export markets works with out-growers (individual farmers or coops) on production.

Birds' eye chili is a traditional crop (grown in the wild) in Rwanda, but other types of chilies are not. All types of chilies have strong potential for Rwanda and are an ideal high-value crop, suitable for the climate and the intensive use of land. Both the fresh and dried exporters report significant demand in end markets that far outstrips their ability to supply.

The growth of the fresh green chili sector of the market was hampered by the pioneer buyer / exporter providing sub-quality seeds that impacted production and led to abandonment of the crop by many of their out-growers. current exporter continues to export and hopefully those early challenges will be replaced by a more stable situation going forward.

Few statistics are available as this crop is not broken out in MINAGRI or RAB statistics, and only appeared marginally in the 2015 EU Horticulture Survey.

FAOSTAT reports that in 2013, 400 hectares were cultivated and 5,400 tons produced in Rwanda, a figure that includes all fresh chilies.

The exports of fresh chilies align with the government of Rwanda's stated aim to increase the horticulture export sector of high value crops, as outlined in the Rwandan Government's Strategic Plan for the Transformation of Agriculture Phase III, under the initiative 3.3.4.a. Dried chilies are also included in this strategic objective.

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

The focus of the value chain analysis is on fresh Green Chilies, however the entire chili industry is also included in certain sections, because: 1) fresh exports are currently such a small industry; 2) there is considerable overlap between varieties in terms of their uses, and their potential for processing, and 3) a critical part of a healthy fresh export industry is building a secondary

processing market and / or local fresh market.
The following section breaks down each stage of the green chili value chain (Inputs; Production; Harvest and Postharvest; Marketing and Distribution; Processing, as well as Policy/Operating Environment).

GOVERNMENT / OPERATING ENVIRONMENT

As noted in the Horticulture Overview, the government has a strong and vital role to play in developing horticulture in general. Rwanda has a well-organized extension system throughout the country, but there is little attention given to horticultural crops by extensionists As extension services are not horticulture-focused and few agronomists specialize or are trained in horticulture and especially in green chilies.

Financing is a common complaint in horticulture, but more so for chilies which is largely an unknown and untested crop in Rwanda, and where set up can be costly.

INPUTS

Rwanda has some homegrown knowledge of and cultural basis for the crop, for birds' eye chilies in particular. Currently there is testing, by a potential private sector investor, of appropriate varieties of green chilies for drying purposes (not fresh). The history of low quality seeds represents at least a learning curve and has driven awareness amongst producers of the need for high quality, certified seeds.

Challenges include:

Quality seeds are unavailable or too expensive

- The industry is not big enough to have attracted the interest of the private sector agro-input providers
- RAB has no certification programs for chili seeds
- Negative history with bad quality seeds being provided by exporter, leading to complete replanting by some farmers and abandonment by others

Agricultural input companies are not prepared for this market or product

- Only obtain inputs via special order
- Unlikely to be drivers of this industry due to small demand

Pesticide use is low and may be inappropriate

- Specialty chemicals need to be sourced from Uganda or Kenya
- Low local knowledge of appropriate pesticides

Lack of fertilizers specifically for chili plants

The priority areas for reducing losses in the chili value chain are:

- Better packing techniques and materials
- Better sorting and grading
- Better storage techniques and equipment

PRODUCTION

Chilies represents a centrally managed value chain and many smallholders are supported in production by their buyers (either exporters or processors), with potential for the buyer to guide production and share their resources and experience. Certain areas of the country are becoming hubs of production (Rusizi, Ngoma and Nyagatare), with potential for clustering effects. Some varieties require little production knowhow and are a relatively simple crop to grow, making it ideal for smallholders (BEC; green). Once established, production and labor costs are low on a hectare of chilies compared to other crops.

Production-related challenges include:

Lack of land available for entrepreneurs wanting to invest in this industry

- The industry has the potential to attract larger-scale entrepreneurs, but access to land remains a perennial problem

Lack of knowledge about production practices

- High susceptibility to disease (SB and GC)
- Lack of irrigation
- Almost complete lack of extension support

No certification for production at the out-grower level

HARVEST AND POST-HARVEST

For chilies, some varieties have a relatively long shelf life, especially green chilies. Buyer-led production model allows for transfer of knowledge, and interventions and training in harvest and post-harvest techniques, and the collection system from producers by the current exporter means less travel and transport issues for smallholders

Key Harvest and Post-Harvest challenges include:

Harvest is very labor-intensive and risky

- Harvesting is labor intensive and sometimes there are labor shortages
- Rain during harvest poses a threat to the quality of the product and there is no material available (sheeting) to protect crops

Lack of knowledge about harvest and post-harvest best practices:

- Low awareness of good harvesting practices
- Low awareness of needs of export market, including quality requirements and appropriate sorting

Extreme post-harvest losses for export

- Up to 80%, reflecting both the exigencies of export market and lack of appropriate sorting at the farm level

Lack of appropriate storage

- No cold storage on farm or at collection point or in truck to prolong shelf life

Packaging materials are scarce

- Appropriate materials are underutilized at the farm level – transport done in bags instead of crates

For fresh chilies, disconnected and non-transparent sorting system with high externality issues

- Losses during transport become farmers' risk, not buyer's risk
- No incentive from buyer/exporter to minimize degradation of product once it is in his hands; he only pays for what he exports
- Main sorting happens at the pack house in Kigali, removed from farm, **creating a disconnected and non-transparent system that results in huge losses overall**

MARKETING AND DISTRIBUTION

Overview of the marketing and distribution system for the chilies (general):

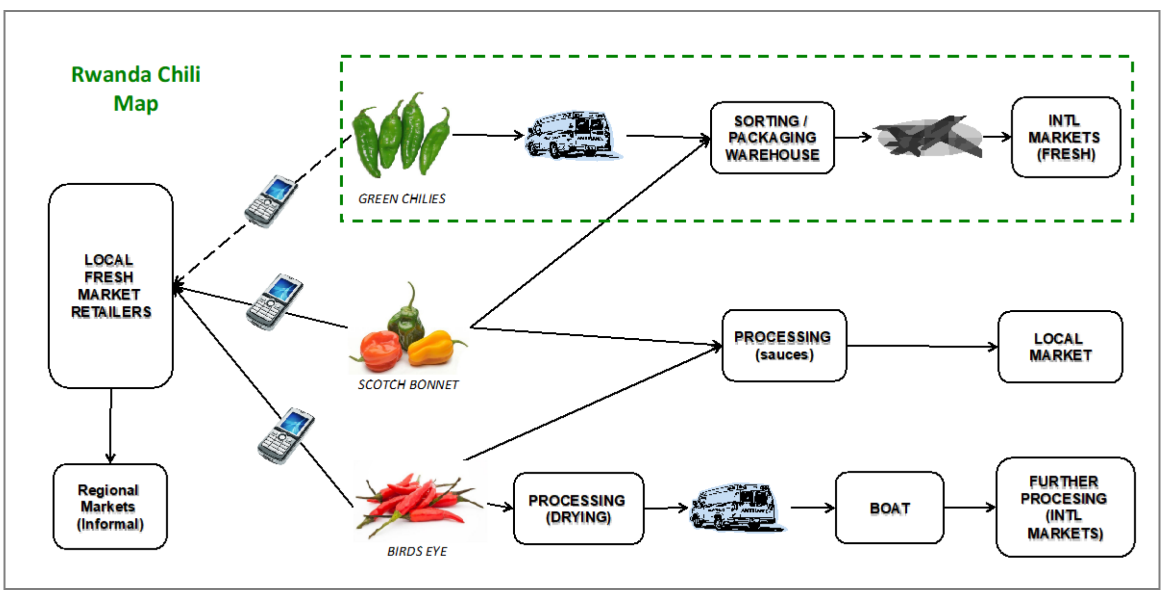

Figure 1: Rwanda Chili Map

Currently, NAEB's programs and infrastructure are supportive of exporters, including work on market linkages, export process help, certification support and provision of space for pack houses and sorting houses, and new initiatives around airfreight subsidies are coming on board by 2017. New investment (Garden Fresh) in fresh green chili exports will move industry away from current monopsony of one buyer. The dried product has no issues of airfreight and minimum quantity that constrain fresh exports

By all accounts, demand for chilies (both fresh and dried) is strong and all clients expressed a need for more supply. In addition, there is a growing local market for fresh (though not green) and interesting regional potential. Short local market chains benefit producers, via use of mobile phones and mobile payment systems to create direct lines between buyers and sellers (local market), and there are currently no middlemen operating in this space.

Despite these positives, several key challenges remain:

Green chilies have limited buyers (monopsony):

- Producers are at the mercy of one buyer and there is no healthy competition

Export market access remains challenging:

- Currently fresh exports are not certified, greatly limiting their export and expansion potential.
- Airfreight costs for fresh produce are high
- Price fluctuations on the international market
- Lack of knowledge about end markets

Small to non-existent local markets:

- Especially for green chilies
- No processing market for green chilies
- Little local demand for fresh, including secondary and tertiary quality product

PROCESSING

Rwanda has a relatively successful and long history of drying - PEBEC (birds' eye chilies) has been working for a decade and is well established, and currently works with 12,000 out growers – as well as sauce and oil making – Urwibutso is a major buyer and producer of hot sauces and oils. In addition, new processing projects are in the works, including one under the aegis of SITA (Supporting India's Trade Preference for Africa) for a project for drying green chilies in Bugesera region.

The following is an overview of chili processing and value-add potential:

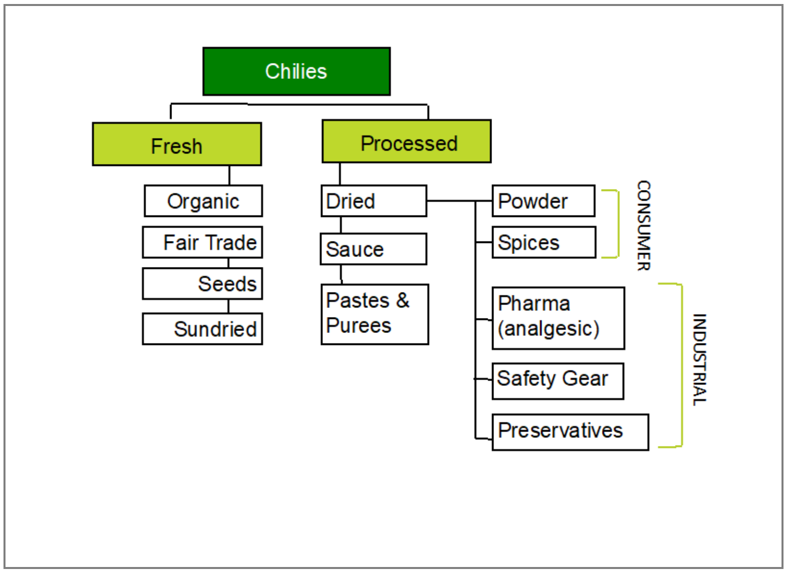

Figure 2: Chili Processing and Value-Addition

Key challenges for processing include:

Currently no secondary processing for green chilies and limited for hot pepper

- To absorb and add value to secondary and tertiary quality product
- Limited connection for non-PEBEC producers (birds eye chilies) to sell their secondary product

Risk of "supply driven" investing in green chilies

- "We have the product, let's do something with it"

Lack of processing constrains growth of fresh market and vice versa

Lack of capital for drying entrepreneurs to expand drying infrastructure

CHILI ACTORS AND MARKET SYSTEMS

A. PRODUCERS

There are several types of producers involved in the chili industry:

- **Independent smallholders** – very few and only serving local and regional market
- **Smallholders working with larger exporters / buyers** who also have the market linkages – the out-grower model
- Medium-sized **entrepreneurial farmers** – the chili sector seems to have attracted a fair number of "agripreneurs" not coming from a traditional farmer background. These investors either attempt export themselves, or work with exporters to find their markets.
- **Cooperatives –** engaged in chili production, often of various types, working with either a fresh exporter or dried (BEC)

- **Exporters producing on their own land, and also working with out-growers**– the current potential investor into fresh exports of green chilies (Garden Fresh) fits into this model

B. CHILI EXPORTERS

The export portion of the Rwandan horticulture industry is still very much in its infancy. The industry is poised for take-off, but is still encountering issues. The following graph shows the evolution of a horticulture industry, from an investment point of view:

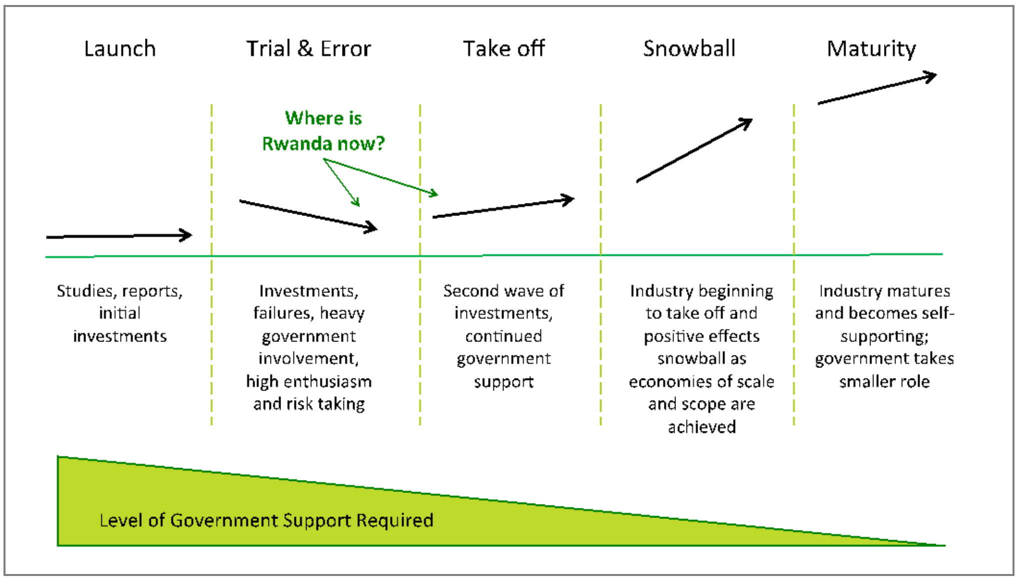

Figure 3: Evolution of Horticulture as an Industry

Export markets, though rewarding, are difficult to access and stringent in terms of quality, quantity (both volume and consistency), certifications required, risk and volatility, etc., etc. Realistically, they are beyond the current capabilities of even well-organized cooperatives, and certainly beyond the reach of the average Rwandan farmer. The group with the best (or only) access to these markets are dedicated exporters with the capital, market linkages and experience required.

The Rwandan government recognizes the key role of private sector exports in growing the horticulture export sector, and list the following benefits in their PSTA III:

- Economic and managerial sustainability of enterprises and value chains
- Access to and timely provision of the specialized expertise that the sector will increasingly need
- Access to resources required for investments in productive facilities
- Pricing of inputs and outputs based on market criteria and creating greater efficiency

In the early days of the launch of a horticulture industry, these exporters bear an outsize burden as they struggle with underdeveloped infrastructure and uncertain supply. Currently there are approximately 17 fresh exporters working with NAEB, though because of the existing challenges in this value chain, some of the companies go in and out of business, or may temporarily halt exports.

Nonetheless they are the key to the future development of the industry and should be supported as much as possible. These early investors can be termed “pioneers” and though they will eventually operate independently, in the early stages of development there is a strong role for government support.

C. END MARKETS OVERVIEW

Export markets are currently in Europe. Demand is high, but requirements, in terms of quality and quantity, are also high. These markets are out of reach of smaller producers (or even medium and large single producers) who lack the necessary quantities and certifications to interest importers in Europe.

Currently, as noted above, there is only one exporter and one potential investor in the fresh green space. More study can and should be done to quantify the European export markets and understand importer requirements. This will serve as a road map for investors looking to enter into this industry, which by all accounts is an interesting one.

Local markets for fresh green chilies include small local consumption in cooking (both Scotch Bonnet and BEC are far more commonly used in local cuisine). Smaller specialty markets, for example with the Chinese community, do exist, and while they might have potential for future growth, their current size remains small.

Local traders pay up to 800 fr/kg. Bags of fresh scotch bonnet retail for 1600 fr/kg to 2000 fr/kg on the local market, the same price as green chilies (though it should be noted only that in the entire Nyabugogo wholesale market (the largest in Kigali) only one seller of fresh green chilies was found.

Green chilies are consumed more frequently in **regional markets**, specifically Uganda and the DR Congo. Rusizi, one of the prime chili producing regions, is located close to the Congolese border, and there is a small and informal trade between traders buying and agglomerating chilies for this market. Some of the producers and retailers in Kigali act as a wholesaler for Goma buyers via Gisenyi.

Though the local market is small, retailers expressed a preference for green chilies because it has a longer shelf life relative to hot pepper.

As noted above, on the local market, the distribution and marketing chain for chilies is compressed, and there is almost complete disintermediation of middlemen and the primary relationship, for the local market, is direct between farmers and retailers (who also occasionally act as wholesaler).

This direct contact is probably due to the size of the industry (i.e. small) and can be expected to disappear somewhat if demand and production grow and middlemen enter.

Long-term prospects for demand in the local fresh market remain uncertain.

D. VALUE ANALYSIS – FRESH GREEN CHILI

As the fresh export chili value chain is relatively short and compressed, there is little likelihood or need for producers to take a forward position. Currently the exporter pays for transport. As noted above, the key need is on improving post-harvest handling and sorting at the farm-level, and increase transparency and develop a system of returns and / or alternate uses for the non-used chilies.

The following graphic shows the current situation as well as the potential future scenario were some of these changes to be implemented:

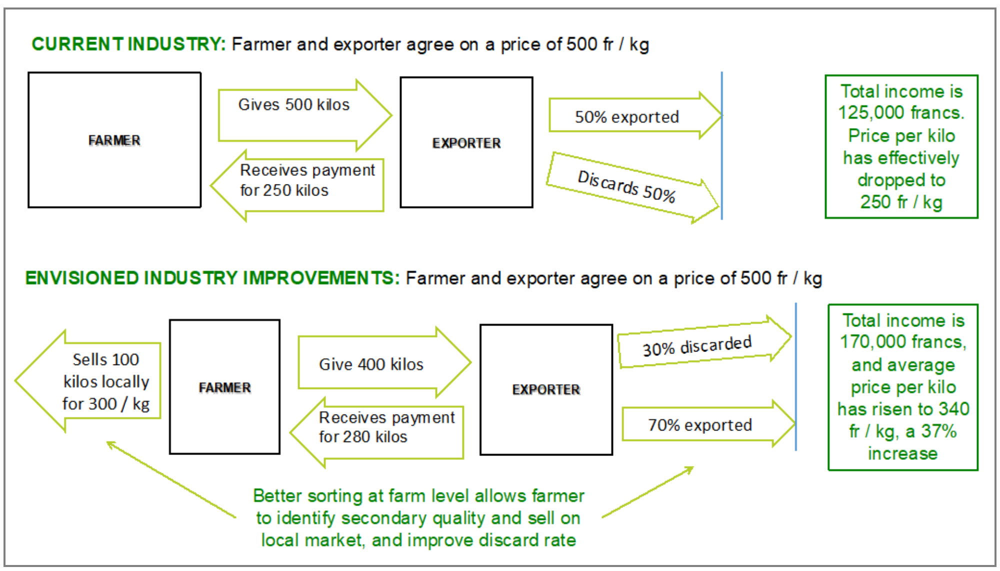

Figure 4: Sample Analysis of Post-Harvest System Improvements

Where a processing option to be implemented, the changes would be even more beneficial as the discard rate would decrease substantially and economic losses would be improved**.**

Recommendations

A. VALUE CHAIN INTERVENTIONS

The following interventions are divided into two main categories: those that exist at an enabling environment or government level, and those that may be within the scope of the Postharvest Centers, for example those interventions that are training or capacity building based; those that are collaborative, cluster building, and focused on facilitation and bringing producers together, and finally those that require only minimal investment in equipment or materials. We anticipate that not all 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.

INPUTS & PRODUCTION - RECOMMENDATIONS

Government and Policy-Level Interventions

- Encourage or mandate use of certified seeds only
- Encourage and / or work with exporters to fund or subsidize seeds and fertilizers
- Educate extension services and RAB on chilies and chili potential

Potential Project-Level Interventions

- Identify appropriate varieties and seeds for fresh export
- Develop partnerships between exporters, NAEB, RAB and private supply companies specifically focused on chilies
- Exporters and buyers need to integrate themselves into production decisions more closely and work closer with producers
- Support for entrepreneurs to work with producers
    - Exploration of different models for this – see belowfor more detail
    - Strengthening production training and extension between private companies and out-growers
    - Work with buyers /exporters to develop demo plots to educate and train farmers and / or incorporate the Training Centers' demo plots into their efforts
- Work with NAEB to disseminate production practices for certification (in advance of certification)

HARVEST AND POST HARVEST RECOMMENDATIONS

Government and Policy-Level Interventions

- Support implementation of crates for targeted number of agricultural crops and commodities.
- Continue government support for *Ubudehe* program targeting improvement of small and secondary roads
- Continue support for development of local packaging industry

Potential Project-Level Interventions

As noted above, **a major need in this export model is to move the sorting and grading (key post-harvest functions) closer to the farmer**, to both reduce the losses and improve transparency.

- Opaque, non-transparent packing system needs to be overhauled to benefit both exporter and the producers
  - Establish sorting areas on farms or in nearby collection areas
  - Much better pre-truck sorting and grading needs to happen
  - Improving handling and potential cold storage at truck level
  - Work on "returns" system and / or compensation
- Provide training in appropriate harvest and post-harvest handling
- Implement low technology and low energy cooling solutions at farm level and also at truck level
- Develop Horticulture Discretion Fund for purchases related to post harvest equipment and materials

MARKETING & DISTRIBUTION

Government and Policy-Level Interventions

- Build extension service capacities to relay market information and market access information
  - Emphasis on helping producers research the market and marketing options *before* planting
- Support land consolidation schemes, informal farmer associations and collaboration efforts in order to increase volumes and yields
- Support development of the Kigali Wholesale Market project and ensure that small farmer needs and requirements are incorporated as much as possible
- Migrate and extend e-SOKO system by developing mobile applications for use on cell phones

Potential Project-Level Interventions

- As noted in the post-harvest section, work with producers and exporters to develop model that will erase issues of extreme opaqueness and lack of transparency and decrease losses
- Support exporters to support their out-growers with international certification schemes
- Promote industry clustering approach across all chilies and all players in the chain
- Investigate potential to improve regional fresh exports, via traders and farmers
- Quantify demand in target end markets (both for fresh and dried) to guide and stimulate investment in this sector
- Work with producers to link to secondary markets (drying, fresh, etc.) as appropriate

PROCESSING RECOMMENDATIONS

Government and Policy-Level Interventions

- Continue support for development of local packaging industry

Potential Project-Level Interventions

- Undertake a detailed market study to determine in depth demand of international buyers and full potential for processing for all types of chilies
- Work with project partners and banks to educate them on possibilities in chili processing, and with exporters or investors wanting to work in this space
- Collaborate with all processors in this industry to determine potential for additional buying from non-incorporated out-growers

B. CAPACITY BUILDING INTERVENTIONS – EXPORT PIONEERS

A key question for the development of a fresh horticulture export industry in general, and for fresh chilies in particular, becomes**how to best support the export pioneers.** These pioneers are at the center, between the market (demand side) the production (supply side) and must be effectively supported in both areas.

MARKETING SUPPORT

Preliminary analysis and research suggests the following are support and training needs of horticulture pioneers. As noted, many of these needs are already being taken care of by a very responsive government, via NAEB, whose core mandate is to promote Rwandan exports, but there is always room for additional resources:

Market Information and Research

- Case studies from other countries
- International market opportunities for existing products and exporters
- International product opportunities, for new investment in Rwanda

Market Linkages

- Trade pacts, trade shows
- Investor facilitation
- New market identification and facilitation
- New distribution channel identification

Market Access: Air freight subsidies

- Currently underway

Expansion and Strategic Support

- Business strategy and strategic thinking to develop market-led business plans, not supply led business plans

- Developing downstream processing industries

Entrepreneurial Training

- Small business growth

Financing Support

- Raising bank and other financing institution awareness of horticulture investments and metrics required for success
- Preparation of financing and investment plans

In terms of training and educational needs of export pioneers, there is a supposed study of skills done by the IFC (of all horticulture exporters) but this study was not able to procure it as the IFC said it was confidential and NAEB was unable to provide it to us. As the Training Centers prepares to work with exporters of horticulture crops, we recommend a survey to determine skill level as well as desired training, etc.

PRODUCTION AND SUPPLY SUPPORT FOR PIONNEERS

Support for Certification

- NAEB and other government bodies are currently offering support for both domestic standards and certification, as well as certification for export markets (including GlobalGAP and HAACP)

Production and Training support

- Crucial for producers and out-growers, especially when the crop (like green chilies) is one that is not traditionally grown, and where local government extension services and training likely have little to no knowledge of production and harvesting.

An interesting question, and one where there is a need for clarification, is what should be the responsibility of the private sector and what should be undertaken by the government? For example, is it the responsibility of the exporters to train their out-growers, or should the government take on that responsibility? Both sides will have differing opinions on this, and the answer of course will be a mix of the two.

Support for Post-Harvest Handling

- The exigencies of export markets make this a key need for export pioneers. It is anticipated that the Post Harvest Training Centers will play a central role in this area.

Access to Land and Production

- A core need on the supply side for pioneers is either access to land (for their own production) or product (via out grower models).

Successful fresh exports require a steady supply of good quality produce. Volume is important not just in terms of overall volume, but also consistency of supply. The ability of the horticulture pioneer to secure access to the production needed is one of the key metrics for success for the industry. There are several options for acquiring land and / or production. Given the land constraints in Rwanda, land consolidation is an issue that the government is actively working on and has identified as a priority.

The following graphic highlights some of the different models of production currently in Rwanda, and maps each against the possibility of volume (supply) and market access (to international markets).

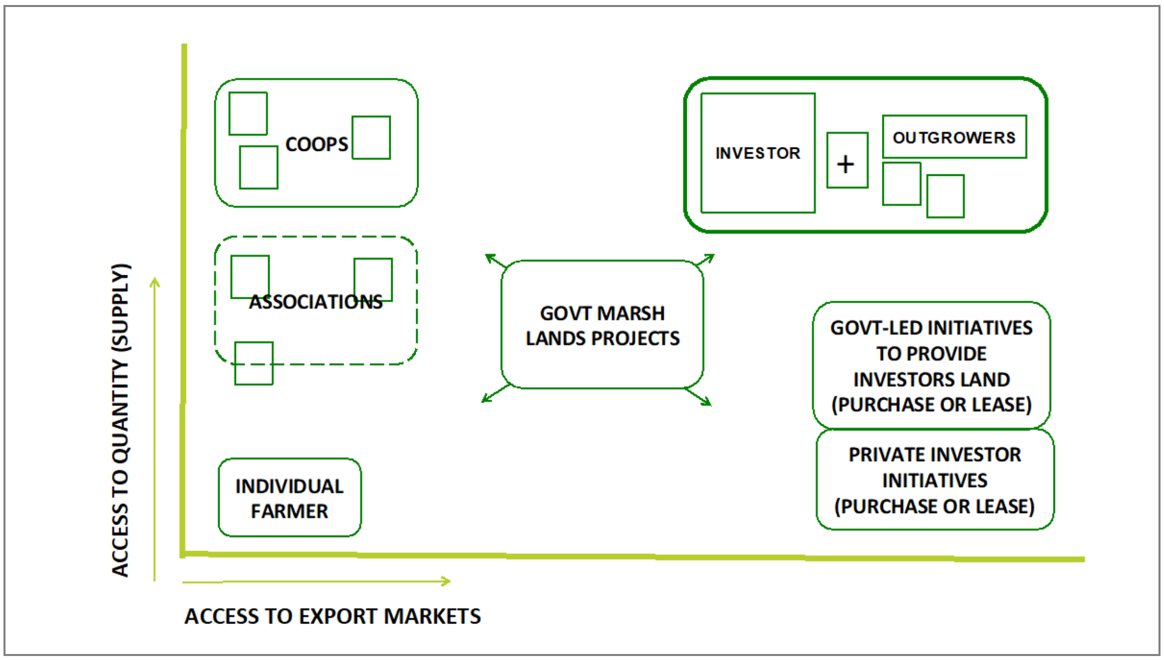

Figure 5: Access to Production and Market Linkages – Different Models

On the left, with high production volumes possible, but low international market linkages, are cooperatives and formal / informal farmer associations. In the middle, because the situation is variable, are producers on government marshland /irrigated land projects. Some of the land is allocated to larger investors, but mostly for non-horticulture crops.

Two options for the private investor looking to secure land are working with the government to identify and consolidate tracts of production land, and private initiatives to either buy or lease land. Both of these offer potential supply, but not large enough to satisfy international exports or even profitability.

In the high right hand corner is the option that best satisfies both requirements: an investment in consolidated land, either through purchase or leasing, coupled with links to producers – the out-grower model. Supply is secured, and market linkages remain high.

In this scenario the exporter is also involved in production, and being a producer enables the exporter to act as lead farmer and have their farm serve as a demonstration plot for their out-growers.

Another way to look at this hybrid option is balancing the need for control against the need for volume. Control, of course, is heavily important in export markets in terms of certification and traceability and production of the desired quality.

- **100% own production (on leased or owned land):** High control, low to medium volume
- **100% out-grower:** Low control, theoretical high volume (though volumes may be impacted by quality issues)
- **Hybrid models:** Balances control and volume.

Where possible and applicable, the Training Centers should support the effective formation of out-grower business models, by helping with identification of potential producers, establishment of linkages (contract, expectations, investment responsibility for start-up) and running of the model (expectations, problem solving, adaptation and growth).

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 and packinghouse for green chilies, an export commodity in Rwanda, have increased the knowledge base in Rwanda and helped 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: Kigali and Nyanza (fresh production), Rulindo, Nyarugenge and Kicukiro (processed products).

The goal of the assessment was to sample postharvest losses for a random selection of 10 farms and 10 packinghouse loads via direct measurements and observations. The major exporter of fresh green chilies chose not to fully cooperate with the CSAM team, so only 7 farms and 4 packinghouse loads were assessed. Additional and supplementary information was gathered via interviews, observations and measured during simulated postharvest handling conditions (by holding harvested produce for 24 hours at ambient temperature). CSAM interviews were conducted with 11 persons, via a stratified sample of known experts, extension workers, farmers, traders, processors and marketers.

Interviews and observations identified several key issues, including once per week harvesting, lack of training for workers and use of inappropriate practices (rough handling, lack of shade, mixing of loads and food safety issues).

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 we 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.

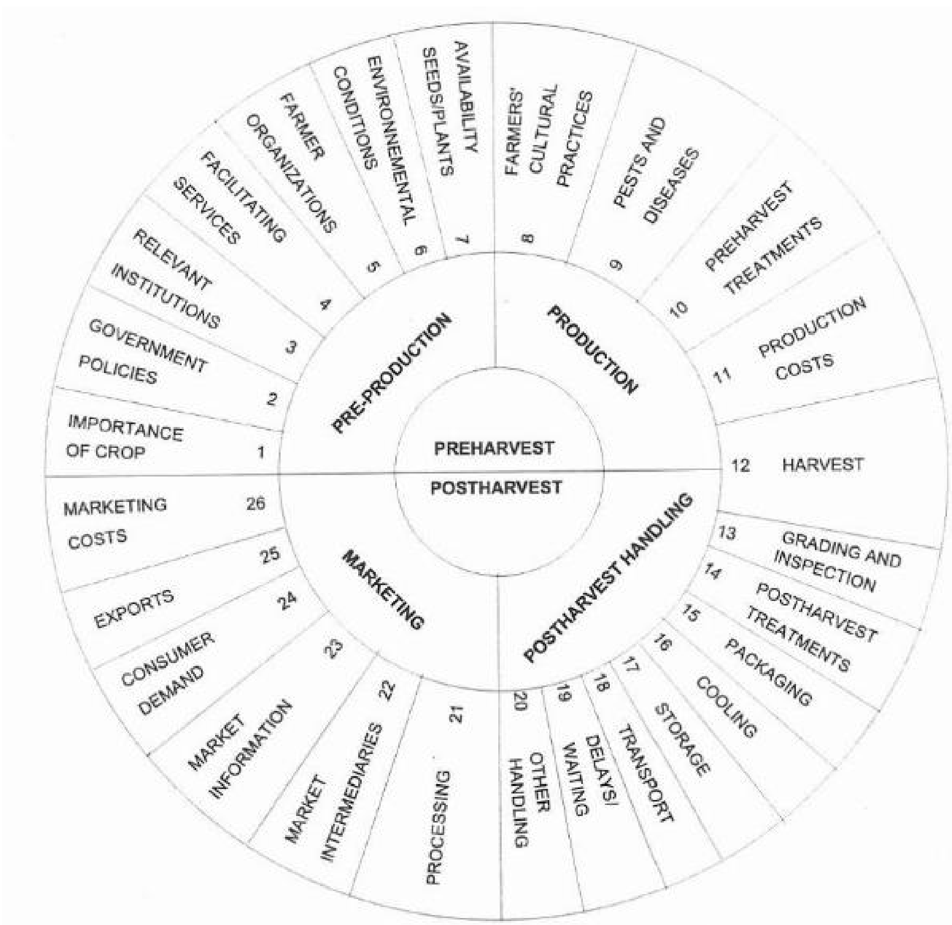

Figure 6: Principal components of a CSAM (LaGra 1990)

Data on the green chilies 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), packinghouse/collection (Annex 1C), 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 1D). The protocols for using the data collection worksheets are included in Annex 1E.

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 team members go to the field carrying with them a set of tools that will help them measure different parameters that will help assess quality and losses. (Annex 1E)

- Scales to assess the weight loss caused by postharvest practices
- Cameras to report the quality of the crop and handling practices at any segment of the value chain
- Digital thermometer (temperature probe) to measure the temperature and the relative humidity of the environment at the time of the visit and the temperature of the chilies
- Quality rating scales and color charts (maturity indices).

Site selection for the Green Chilies CSAM study

The team surveyed the country and identified and labeled attributes to the principal growing areas for green chilies in Jan-March 2017. The areas of green chilies production visited by the team were being grown under irrigated scheme in Nyanza District. Only about one hundred farms are involved in green chili exports. The NAEB packinghouse for green chili exports is located in Kigali. Processing of chilies into dried products and chili oil is being done by private companies in Rulindo, Nyarugenge and Kicukiro Districts, using pili-pili or green birds eye chilies.

The districts that were included in the CSAM study include: Kigali and Nyanza (fresh birds eye chili production), Rulindo, Nyarugenge and Kicukiro (processed products).

Marketplaces were not assessed, since the green chili exports move from the Kigali NAEB packinghouse by road to Entebbe, where they are shipped via air to the UK or Gulf States markets.

Sampling protocols (see Annex 1E and Annex 2)

The goal of the assessment was to sample postharvest losses for a random selection of 10 farms and 10 packinghouse loads via direct measurements and observations. The sole exporter of fresh green chilies did not cooperate directly with the CSAM team, so only 7 farms and 4 packinghouse loads could be fully assessed. Additional and supplementary information was gathered via interviews, observations and measured during simulated postharvest handling conditions (held at ambient conditions for 24 hours after the harvest). CSAM interviews were conducted with 11 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 once per week harvesting, lack of training for workers and use of inappropriate practices (rough handling, lack of shade, mixing of loads and food safety issues).

There were five major reasons for high postharvest losses for green chilies in Rwanda**:**

1. **Mixed maturity at harvest–** Harvesting is done only once per week on average. This leads to mixed maturities at harvest – wide range of sizes and colors, which lowers overall quality grade and lowers he associated market prices.

Figure 7: Mixed Maturity at harvest

Rough handling during harvest –The CSAM Survey identified that the farm workers whether family members or hired ones are not trained how to handle the produce well. The harvesting is done often under hard sun. Pickers remove the green chilies from plants in a rough manner causing damage to the produce and to the plant. They also throw green chilies into the containers.

Figure 8: Rough handling

2. **Poor postharvest handling practices**– Actors in the value chain are not trained in postharvest handling. They throw produce and stack over-filled containers. It was also observed that pickers, picked up produce that had dropped to the ground and put them in the collection containers.

Figure 9: Green chilies in stacked plastic crates, chilies fall out of vent holes, get crushed between crates.

3. **Lack of use of shade –** Farmers do not use any type of shade in the field. When the chilies

are being transported there is no facility for temperature management. This speeds the ripening and deterioration of the green chilies, causing water loss and weight loss.

Figure 10: Field container of green chilies waiting for transport

4. **Rough transportation–**During transportation, the chilies are exposed to sun, heat, wind and handling damage. They also suffer from compression damage in overloaded containers, crushing and bruising of fruit.

Figure 11: Vehicle of fresh produce arriving the NAEB packinghouse.

Overall, rough handling, transport and lack of temperature management resulted in high losses (17 to 24% damage, 13% weight loss and related loss in market value upon arrival at the packinghouse).

The main observations by CSAM component are highlighted below.

Table 1: CSAM Findings Summary - Causes and Sources of Losses for Green Chilies in Rwanda

CSAM Components	Interviews	Observations	Recommendations
PLANNING/ PRE-PRODUCTION	• Export buyer controls everything (seeds, fertilizers, harvest timing and practices) • Seed are saved by exporter to give to farmers between seasons, this can lead to quality deterioration	• One Cool storage room (charcoal cooler) available locally was not in use to store the supply	• Use of cool storage during delays in shipping from farm to packhouse could help maintain quality • High quality seeds should be supplied in each planting season
PRODUCTION		• Irrigated, terraced fields harvested once/week • Mixed maturities at harvest time	• Plan to harvest 2 or 3 times/week for increased yield and improved quality, uniform

			maturity stage
POSTHARVEST	• % sorted out is based on buyer requirements • Grade specifications change depending on market requirements (fresh use vs medicinal vs processing)	• Pickers throw produce into field containers • Filled containers are left sitting in the direct sun	• Use of shade during delays • Gentle handling during picking, use of apron-like harvesting bags (wearable, hands free) • Lots should be labelled and kept separate for weighing, sorting/grading, packing and traceability • Packed cartons should be loosely covered during shipping delays
MARKETING	• Rejects (due to quality specifications or damage) are sometimes returned to a grower representative	• Growers can sell sacks of rejected produce (plus floor sweep) at low prices/kg	• Growers should have more information on buyer specifications prior to packing operations

Postharvest Quality and Food Safety

All of the harvested fruits were packed in vented plastic crates and moved via company supplied pick-up truck to a central packing facility, located at NAEB in Kigali. Packers were all women, trained by the NAEB supervisor and packinghouse manager to sort and grade the produce. Other types of fresh produce (okra, capsicum, bitter gourd, etc.) and was observed stacked nearby, and appeared to be dehydrating (becoming less glossy) and losing freshness during shipping delays.

Figure 12: Filled package of 5.3 kg

The Journey from Farm to Market

The size of the green chili farms included in the sample for data collection measurements ranged from 1 to 3.5 hectares (average size 1.6 ha). The distance to market was the same for all the farms producing green chilies, since the production was in one location and the buyer was a sole exporting company (located in Kigali, 114 km away). The data collected on farms was either during or within 1 hour of the harvest.

All of the harvested fruits wasmoved via company supplied pick-up truck to a central packing facility, located at NAEB in Kigali.

Quality characteristics such as ripeness and firmness were measured on the farm and in the packinghouse, and were determined to be uniformly dark green and firm.Export quality (Grade 1; 700 Rwf/kg) has strict size and shape requirements, while medicinal quality (Grade 1; 600 Rwf/kg) is much less strict. Grade 2 is of much lower value (200 Rwf/kg) and is not purchased by the exporter but returned to the growers, then usually sold on the local market or to exporters who transport the fruits to the Congo.

Table 2: Quality characteristics for green chilies in Rwanda

Chilies	N	Relative perishability*	Air Temp °C	Pulp Temp °C	Package protection**	Color	Firmness
Farm	7	3	26.6	30.2	5	94% dark green 6% immature	5
Packing house	4	3	23.9	23.3	5	100% 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 Green Chilies

The measurements of percent discards, defects, decay and mechanical damage for green chilies in Rwanda are summarized in the table below. Damage and defects were relatively low, but quality issues generally resulted in a lower sales price for Grade 2 produce. Only a small amount was rejected outright due to serious defects or damage.

Table 3: Postharvest % losses for green chilies in Rwanda

Green chilies	N	Avg Time from harvest	Ripeness	% defects	% decay	% mechanical damage
Farm	7	1 hour	Dark green	46%	57%	24%
Packing-house	4	24 hours	Dark green	22%	0%	17%

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

Table 4: NAEB Packinghouse sorting/grading measurements and market value for green chilies

Date	Farms/ production weight measured at the packhouse (24 hours after harvest)	Grade 1 600 Rwf/kg	Grade 2 200 Rwf/kg	Rejected no value
26 Jan	4 farms; 376 kg harvested and handled as a bulk load	78% 295 kg 177,000 Rwf	19% 70 kg 14,000 Rwf	3% 11 kg
9 Feb	3 farms; 160 kg harvested and handled as a bulk load	73% 117 kg 70,200 Rwf	27% 43 kg 8,600 Rwf	
Total packed	7 farms: 536 kg on arrival	73 to 78% Grade 1	19 to 27% Grade 2	3% rejected

These findings are similar to those reported for fruits and vegetable crops in Rwanda during past assessments (WFLO 2010; Kitinoja and Alhassan 2012; van Dijk et al 2015; Kitinoja and Kader 2015). Mechanical damage due to rough handling and throwing/dropping produce during harvesting and packing is a common problem. Use of plastic crates for transport is a positive practice, contributing to lower postharvest losses.

Weight loss due to water loss is also a problem for the green chili crop. Estimates are based upon simulated postharvest delay of 24 hours between the harvest time and the arrival at the NAEB packinghouse in Kigali. Samples were taken (20 fruits from each farm) and the weight was measured at the time of harvest and again after 24 hours.

Table 5: Measured changes in weight in 24 hours after harvesting (samples of 20 fresh fruits)

Farm	Initial weight (g)	Final weight (g)	% weight loss
01	62	59	4.8
02	77	66	14.3
03	77	69	11.7
04	58	49	19.0
05	73	66	9.6
06A	63	56	11.1
06B	58	51	13.7
Average weight loss			12.7%

Estimated value of postharvest losses

The green chilies are weighed upon arrival at the NAEB packinghouse in Kigali, so any losses prior to arrival are directly experienced as losses in earnings for the farmers. The lack of temperature management during transport means that weight losses range from 5 to 19%, depending on the weather (temperature, relative humidity) and any delays in transport (added exposure to sun, wind).

The sole exporter is in total control of the timing of pickup of the produce from the farms and of the means of transport and delivery to the NAEB packinghouse.

If the green chilies crop in Rwanda is experiencing a similar loss in quality during the farm to packinghouse as that measured in this CSAM study, this equates to an average loss in market value of 13%. If the total annual production of chili peppers is 4,500 tonnes, and the market value per kg ranges from 200 to 600 Rwf, this equates to a loss in market value of $US 250,000 to $625,000 per year.

Table 6: Estimated range of the value of postharvest losses of green chilies in Rwanda

Annual Production (2014)	Market value range (high quality)	Market value range (low quality)	Range of Annual economic loss in Rwf	Range of Annual economic loss in $US
4,500 tonnes	600 Rwf/kg	200 Rwf/kg		

4,500,000 kg	3.6 billion Rwf	1.2 billion Rwf		
13% weight loss 3,915,000 kg	3.1 billion Rwf	1 billion Rwf	0.2 to 0.5 billion	$250,000 to $625,000

800 Rwf = $US 1

At the wholesale market level, the estimated loss reported by traders and sellers is 35% (expected losses). At Nyabugogo market, the wholesale buyer is responsible for the loss, but in the case where losses are higher than normally expected, the woven wholesale basket is pointed out and the loss is covered by producer by reducing the normal price.

Costs and Benefits of improved postharvest practices for green chilies

The first example is for use of maturity indices during the harvesting, and harvesting 2 times per week. Harvesting more than once per week stimulates growth of new fruits, reduces loss of fruits due to over-maturity and generates an immediate increased profit of $65 for each 1000 kg load.

Table 7: Use of maturity indices for green chili harvesting twice per week

Start with 1000kg	Current Practice	New Practice
	Harvest once per week, mixed maturities	Harvest two times per week, all fruits at dark green stage, proper size and maturity for Grade 1
COST		
Labor for extra harvest		5000 Rwf ($US5) for 5 persons
Cool storage in charcoal cool room until pickup		1000 per day for 3 days = 3000 Rwf
Relative cost		+ 8000 Rwf ($US10)
BENEFITS		
% Loss	75% grade 1 25% grade 2	90% grade 1 10% grade 2
Amount to sell	1000 kg	1000kg
Value per kg (excellent quality)	750 kg at 600 Rwf ($0.75) 250 kg at 200 Rwf ($0.25)	900 kg at 600 Rwf ($0.75) 100 kg at 200 Rwf ($0.25)
Total market value	450,000 Rwf 50,000 = 500,000 Rwf ($US 625)	540,000 Rwf 20,000 = 560,000 Rwf ($US 700)
Market value - costs	$625	$700 – 10 = $690

Relative profits		+ $65
ROI		Generates an immediate increased profit of $65 for each 1000 kg load.

The second cost/benefit example is for the use of shade to protect the green chili 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 only 10 uses. Each subsequent use generates an additional $6 per load of 100kg.

Table 8: Use of shade for harvested green chilies in Rwanda during delays and transport

Start with 100kg	Current Practice	New Practice
	Leaving piles or containers of fruits in the direct sun	Use of shade to provide lower temperature for produce during delays, transport or marketing
COST		
Simple shade structure, portable	No cost	$US 50
BENEFITS		
% Loss	13%	5%
Amount to sell	87 kg	95 kg
Value per kg (excellent quality)	$0.75 (600 Rwf)	$0.75 (600 Rwf)
Total market value	$65.25	$71.25
Relative profits		+ 6.00
ROI		10 uses fully pays for the shade structure, each subsequent use generates an additional $6 per load of 100kg.

The third cost/benefit example is on the small scale manufacturing of green chili powder. 18 kg of fresh green chilies will produce 1 kg of dried chili powder. The retail value of dried green chili powder in the USA and the EU is $140 per kg, so the wholesale price is used in this worksheet ($70/kg).

Table 9: Green chili powder

Start with 1000kg fresh green chilies	Current Practice	New Practice
	Selling Grade 2 fresh	Manufacture of dried green chili powder

	green chilies in the local market	(Processing via drying and grinding, packaging)
COST		
Labor	No cost	Trimming, slicing, removing seeds labor: 5 people for one day $US 10
Solar drying		Labor for laying our chilies, turning, collecting dried fruits: $2
Packages		110 jars for 500mg each = $110
Relative costs		+ $US 122
BENEFITS		
% Loss		
Amount to sell	1000 kg	55 kg
Value per kg (excellent quality)	$0.25 (200 Rwf)	$70 (56,000 Rwf)
Total market value	200,000 Rwf (US$250)	3.08 million Rwf (US$ 3850)
Market value – costs		$3850-122 = $3,728
Relative profits		+ $US 3,478
ROI		Immediate profit

Recommendations

Green chilies are a relatively new horticultural crop for Rwanda, but past research has identified many appropriate handling practices and improved technologies for green birds eye chilies and many other similar types of green and red chilies. Four major recommendations are provided to guide the project.

1) Training of trainers (capacity building) in improved green chili handling on the farm
Leaders of cooperatives involved in chilli production should be trained in harvest indices, multiple harvests/week, postharvest handling, sorting/grading standards, and use of shade.

2) Training packing house operations
Packers need to be trained on the management of individual loads, recordkeeping and the use of gentle handling, food safety and hygienic food handling practices.

3) Demonstrations that are recommended for the Postharvest Training and Services Centers on

cost effective practices for reducing postharvest losses in green chilies (and other similar chili peppers) include:

- Maturity indices, quality and shelf life
- Use of picking aprons/wearable harvesting bags
- Use of shade (various types of simple, low cost structures and portable shade such as market umbrellas)
- Management of the Charcoal cool room and Zero Energy Cool Chambers (brick and sand, 100 kg capacity) for temporary cool storage
- Small-scale green chili processing methods for value addition (solar drying, sauce making, chili oils)

4) Postharvest agri-business opportunities for green chilies should be promoted. These include:

- Trader/grower partnerships, where improved green chili production, harvest practices and postharvest handling on the farm leads to increased profits for both the growers and the traders.
- Local manufacture of dried cut green chilies (currently imported from India and China) green chili paste, sauces, salsas, dried powders and oils (with flavors, package sizes and prices targeted to local consumer preferences).

A few recommended postharvest technologies 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 low of green chilies by the time that they reach the packinghouse. If there are reliable cold chains facilities which can regulate temperature that is favorable for fresh green chilies (12 to 15^0 C rather than the current ambient temperature of 25^0 C) the shelf life could be doubled.

Introduction of evaporative cooling system will greatly reduce losses of produce at the collection centers as green chilies will have a longer shelf-life after picking time. A charcoal cool room (which exists near the farms but is not in use) or a Zero Energy Cool Chamber (ZECC) that doesn't require any power to operate can keep the produce stored in the chamber cool. These technologies and several other cold chain management options have been fully described in Kitinoja (2013), Kitinoja and Thompson (2008) and Winrock (2009).

2) Picking bags/harvesting aids
The use of low cost picking bags for green chilies would eliminate some of the on-farm handling and damage during harvesting.

Picking bags (commercial product, left. http://www.orchardvalleysupply.com) and handmade canvas cloth version (right; Photo credit: Lisa Kitinoja).

Figure 13: Picking bags

Figure 14: Picking bags being demonstrated in Tanzania at the PTSC in Arusha.

3) Processing and packaging

Processing and packaging of green chilies is not commonly done in Rwanda, but there are many processed food products made using green chilies, or green chili fruits allowed to ripen to red color.

Packaging must be high quality and appropriate for the product. The farmers will need to provide a continuous high quality supply to the industry in order for the industry to be sustainable.

There are examples reported where export rejected chilies are being sold at Rwf 1000 per 200g package at the supermarkets, so there is a small but known consumer demand.

Identification of research needs for green chilies in Rwanda

CSAM study results:

- Chili seed multiplication (breeding): research is needed to find the best seed varieties that would suit the location.
- Some of the insect pests, including thrips and white flies, are reducing production of chilies especially on farms which are located close to forest: research is needed to find out if it is appropriate to grow chilies so close to the forest.
- Improved methods for drying and processing green chilies.

Identification of training needs for reducing postharvest losses

The following are provided as guidance for reducing green chili losses in Rwanda:

1) Farmers need to be trained on pests/diseases management and proper application of pesticides
2) Farmers need to be trained on international market standards and protocols such as GlobalGap certification
3) Farmers need to be trained on marketing (and cost benefit analysis)
4) Farmers need to be trained on improved harvesting and postharvest handling practices (harvesting practices, use of color charts to determine maturity indices, grading etc.).

Advocacy issues/enabling environment factors affecting the postharvest losses of crop

The following are advocacy issues for reducing postharvest losses of green chilies in Rwanda.

- Increase access to improved varieties of green chilies (pest resistant, high quality fresh market, plus varieties for processing)
- Improving rural roads to reduce delays and minimize rough transport
- Provide more support for training extension/outreach staff in pest management and postharvest "best practices"
- Promotion and investment in a cool chain for postharvest handling, storage and transport of perishable foods
- Development of a packing facility closer to the farms, equipped with a cool room
- Promotion and support for more buyers/exporters, since currently farmers have no choice regarding who to sell their produce to, when, how and at what price.
- Support the development of secondary markets for value addition/food processing and appropriate packaging


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5. LIFE CYCLE ASSESSMENT

Methodology

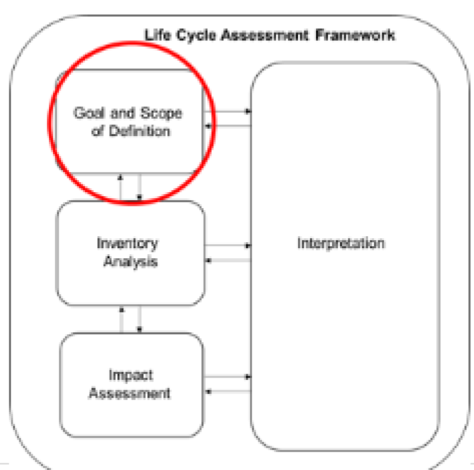
Postharvest loss occur across the value chain for all crops in all economies, however, in Rwanda there are particularly high post-harvest losses. These losses directly reduce the final yield of the saleable and consumable product. Reduced product yield translates to more land, water, fertilizers, chemicals, and other inputs per kg or mass of final product sold to a consumer. Reducing post-harvest 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.

The LCA framework can quantify the wasted resources and land resulting prom post harvest losses. Reducing post-harvest 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.

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 for all three crops, 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.

Water Stress Analysis

Irrigation can increase land productivity and provide crop resistance to irregular weather patterns and increase growing seasons. For these reasons, irrigation practices have been on the rise in Rwanda. There are a variety of irrigation systems currently under construction and the potential of these systems is significant in terms of land productivity (MAIMBO et al 2010).   The Rwandan Irrigation Master Plan developed by the government of Rwanda and the MINAGRI provides a detailed examination of the potential for increased irrigation in Rwanda as well as some of the challenges that these increases will create.

Within water resource accounting, irrigation water is generally referred to as water consumed as it leaves the watershed in which it originates. Water consumption in areas with plentiful water and low water withdraws can be argued to have lower impacts than water consumption in areas that have few water resources and high demand. The Water Use in LCA (WULCA) working group defined a new metric to quantify the impacts of water consumption referred to as Available Water Remaining (AWARE) method. This method aimed to answer the question "What is the potential to deprive another freshwater user (human or ecosystem) by consuming freshwater in this region?" (Boulay et a. 2017) Using this framework to consider water consumption, it becomes clear that the impacts of water consumption are highly dependent on the region where the water is consumed.

When considering water consumption impacts, a characterization factor is used to multiply the liters or volume of water consumed to get a water equivalents consumed. In areas where water is more scarce and has a higher demand, the characterization factor will be higher. Where water is more available and has lower demands, the characterization factors will be lower. Figure 15 shows the characterization factors for Rwanda that are generally higher on the eastern side (shown in red) of the country and lower on the western side near Lake Kivu (shown in yellow). The country characterization factor for the country is 82.4 out of a possible highest value of 100. This indicates that water is more than 80 times more scarce in this region than the world average.

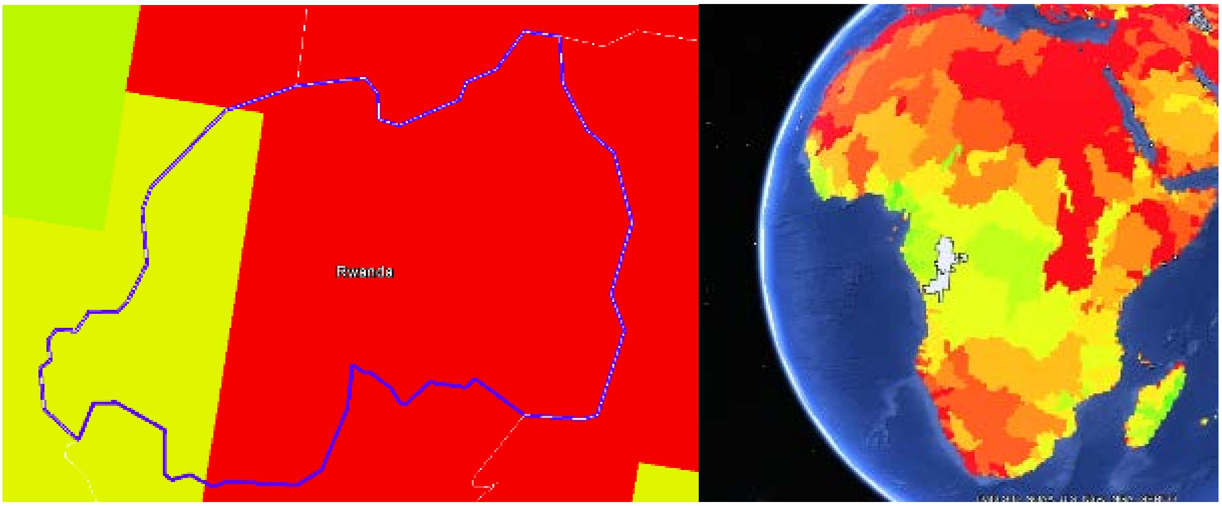


Figure 15: AWARE characterization factors representing water scarcity for Rwanda and Africa

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

There are several types of green chili that are produced in Rwanda that are primarily exported. The Birds Eye Chili that is mostly dried and exported, the Scotch Bonnet Chili that is exported fresh and used locally, and green chilies that are exported fresh as well as consume locally that make up the broader category of green chili production. The production of green chilis is primarily produced by small producers that are reported to be higher than 12,000 growers by the green chili CSAM analysis.

As a country wide crop, few statistics are available and the crop is not listed by MINAGRI or RAB statistics, however, was mentioned to some extent in the 2015 EU Horticulture survey. The 2014 FAOSTAT reported 204 hectares growing green chilis and a total production of 4,500 tonnes of fresh chilis. In recent years, the planted area has declined yet the total production has increased which indicates yield improvements,**Error! Reference source not found.**.

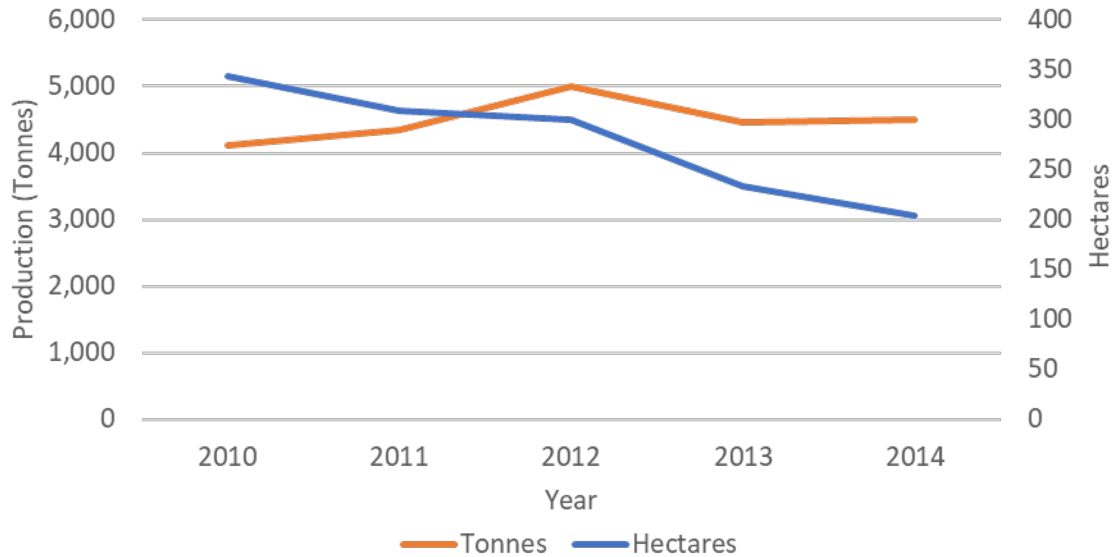


Figure 16: Green chili production and hectares planted in Rwanda (FAOSTAT)

Greenhouse Gas hotspots

Using LCA data representing a world average green pepper data production there are several main GHG hotspots that carry the majority of the environmental burdens, Figure 17. The fertilizer production and use represent 34% and 45% of total GHG emissions, respectively. When combined, they account for 79% of the total GHG emissions associated with global green pepper production. Irrigation is tied as the second largest contributors to GHG emissions. Using petroleum and other fossil fuels to pump water from wells and other surface water supplies requires significant amount of energy which in turn creates GHG emissions. The total emission per tonne of green chili produced is 164 kg CO_2 per tonne, before post harvest losses.

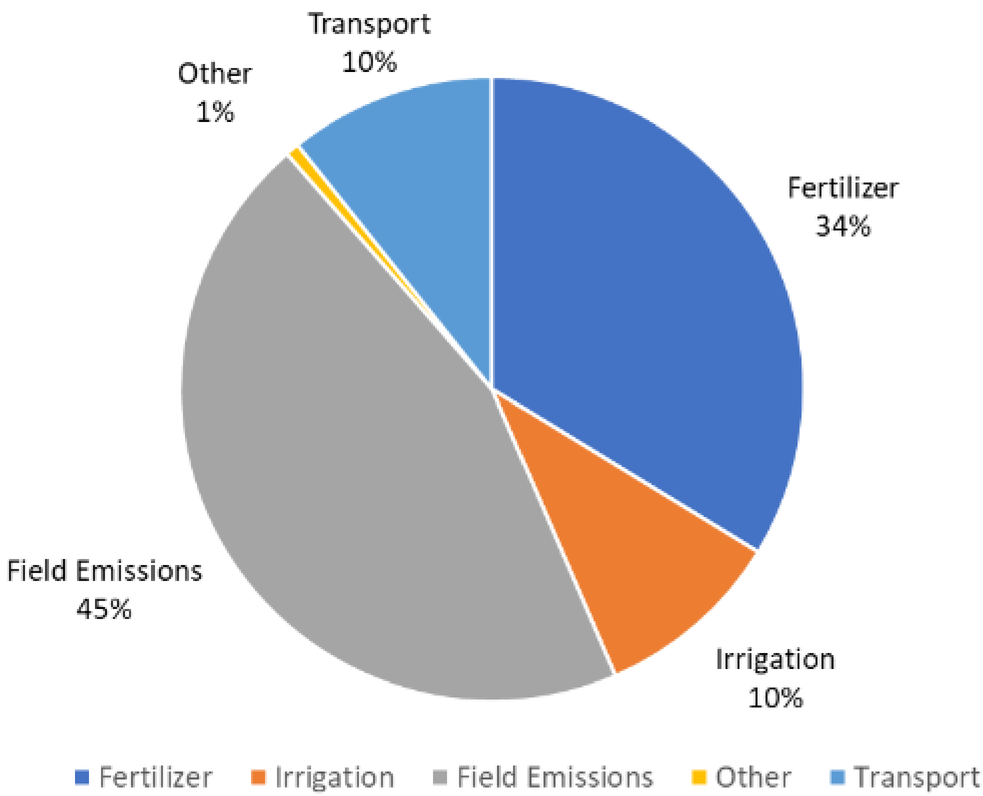


Figure 17: World average pepper production GHG hotspots

Fertilizers represent the largest contributor to GHG emissions for the world average pepper production impacts. The applied fertilizers per tonne and hectare are listed in **Error! Reference source not found.**. The total yield for the world average pepper production was 16 tonnes per hectare which lower than the 22 tonnes per hectare yield reported by the FAOSTAT for 2014 in Rwanda. Though the world average data is not a perfect match to the green chilis in Rwanda, provides us with likely environmental hotspots and will enable further analysis to determine the environmental impacts of post harvest losses.

Table 10: Global average green pepper fertilizer use in kg per tonne

	Kg/tonne	Kg/HA
Potassium sulfate, as K2O	7	112
Ammonium nitrate, as N	4.1	65.6
Phosphate fertilizer, as P2O5	2.1	33.6
Total	13.2	211.2

Irrigation

As with tomatoes, the vast majority of water consumed in the production of green chilis is due to irrigation. Growers use a variety of irrigation practices as reported in the CSAM Assessment. Some crops are hand irrigated while others use furrow and ridges while the recommended approach is drip irrigation. Drip irrigation will generally provide higher water use efficiency and decrease the amount of water consumed per tonne of product. The water consumed in the world average pepper production 38 cubic meters per tonne of produce. When using the AWARE characterization factors accounting for water stress, the total water equivalents consumed are 3300 cubic meters per tonne of chilis.

Impacts of Postharvest Losses
While the green chilis often had diminished value due to post harvest issues, the actual discarded percentage is relatively small. The farms reported discarding 4% on average while the packing house discarded 3%. The damaged produced, however, reduces the value the farmers receive dramatically, however, doesn't increase the environmental impacts of the crop.

Based on these average post harvest losses, they are estimated to create 12 kg CO2 eq. per tonne of chilis. Scaling this to a national production level, 53,000 kg CO2 emissions are associated with post harvest losses. This is equivalent of burning over 6,000 gallons of gasoline. Additionally, when scaled nationally, 170 cubic meters of water are also lost due to post harvest losses.

Recommendations

The Rwandan postharvest supply chain has a high level of losses that were quantified in the CSAM and the value chain analyses. Some losses come in the form of value loss and other in the form of produce that is not eaten. There are specific postharvest supply chain recommendations from both reports that outline key changes that will decrease losses. This report leveraged loss data from the two reports as well as identified the major environmental hotspots within the green chili production process.

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.

The grower survey asked if the farmers performed a soil test to determine the amount of fertilizers needed prior to the application. None of the surveyed farmers used a soil test prior to fertilizer application, however, one grower was planning to in the future. Testing soil prior to fertilizer application is a widespread practice in more advanced agriculture systems that helps the grower deliver the optimal amount of nutrients that maximize yields while reducing the negative aspects of the fertilizer use. With the Rwandan goal to drastically increase fertilizer use, the adoption of soil testing will reduce the wasted fertilizers, increase yields, and avoid unwanted impacts to the environment. It is recognized that fertilizers are still underutilized within Rwanda, however, current fertilizer operations can be improved by soil tests and prevent the negative impacts to soil quality that can occur. To do this, soil tests could be distributed to the farmers or performed by the local agronomist before crop nutrients are applied.

Water resources

The irregularity of water availability makes Rwandan agriculture high risk for non-irrigated growers which makes up the majority of land holders. Government and international donor funded projects have installed irrigation infrastructure in many Rwandan regions as well as drained swamps for agriculture, however, these projects serve a small fraction of farmers and are usually targeted at higher value crops. To serve smallholder farmers, rainwater capture has been proposed to be a viable and low cost option (Jama and Pizarro, 2008). The capture of rainwater that would otherwise go unused for agriculture provides additional resources to growers during the dry season (June to mid-September) while not infringing on the other water needs during the dry season. With increased levels of irrigation availability, the farmer takes on less risk and has a lower chance of a failed crop. With lower crop failure risk, the farmers can more reasonably take on additional financial investment in fertilizers that will increase yields. At a higher level, increased irrigation can lead to higher levels of food security within the country, however, the irrigation needs must be balanced with other water resource needs of humans and the environment in order to avoid unintended consequences of increased irrigation.

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.

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.

JE Austin 2009. Study on Market, Post Harvest and Trade Opportunities for Fruits and Vegetables in Rwandahttp://dx.doi.org/10.1155/2016/6436945 http://dx.doi.org/10.1155/2016/6436945

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.

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.pdfhttp://postharvest.org/Use of cold chains PEF white paper 13-03 final.pdf http://postharvest.org/Use of cold chains PEF white paper 13-03 final.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 Review2010,**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., IlyamaM. 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

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.

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:	
TOMATOES	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 for tomatoes (range of harvesting dates on this farm)				
Name of destination market if known				
Distance to market if known	________km		Expected journey time _____hou	
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 on the vine ______% Reason for sorting out:	Was sorting done before farm gate sale? Yes/No	If Yes, estimate (discarded):___ Reason for sorti
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 catego Large _____% ; Medium ____% ; ____%	
Does price offered vary by quality grade?	Describe grading criteria:		If Yes, what is the price offered quality grade? Highest __ Middle _____ ; Lowest _____	
Expected farm gate price:			Price offered _______ (by weight Volume? By Number of container Price per kg: _______	
MEASUREMENTS	At Harvest		Farm gate (to be measured aga 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				

TOMATOES Worksheet
Code: Farm____

ANNEX 1C: PACKINGHOUSE DATA COLLECTION WORKSHEET

PACKINGHOUSE DATA COLLECTION WORKSHEET		Name of Data Collector:	
TOMATOES	Variety (if known ______________) or describe color, shape, etc		
Code: PACKING____			
Questions and observations	On Arrival		At time of sale
Date			
Name of packinghouse or collection center			
Location of market			
Season for tomatoes (range of dates of sales 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 (discarded):___ Reason for sorti
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 catego Large _____% ; Medium ____% ; S ____%
Does price offered vary by quality grade?	Describe grading criteria:		If Yes, what is the price offered f quality grade? Highest ___ Middle _____ ; Lowest _____
Expected wholesale price:			Price range _______ (by weight? Volume? By Number of container Price per kg: _______
MEASUREMENTS	**on Arrival**		**At time of sale (to be measured if possible)**
Sample size (select random samples)	count of 20		one package (_______ = total nu
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			

TOMATOES Worksheet
Code: PACKING____

Packinghouse

number with obvious defects ie: cracks, sunburn, misshapen, etc		
Describe defects found (take photos)		
	Upon arrival	**Upon loading (to be measured again if possible)**
number with decay symptoms ie: fungus, mildew, bacterial spots, etc		
Describe decay found (take photos)		
number damaged ie: bruises, cuts, mechanical injury, insect damage		
Describe damages found (take photos)		
Ripeness rating: 5=red 4= red with some green	Number red _____	Number red _____
3 = green with some red	Number red w/green ____ # of green w/red _____	Number red w/green ______ # of green w/red ______
2= first sign of red 1=green	Number first red _____ green	Number first red ____ green _____
Rate package protection (mark one with an X)	____5 = very strong, protective ____4 = strong, moderately ____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
Describe package or container: **Type, material, dimensions, cooling efficiency**		
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

Annex 1 D: 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. Green Chilies 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 (Green Chilies Farm01, Green Chilies 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.

COLLECTION CENTER or PACKHOUSE
Data is collected upon arrival and upon sale (loading or departure)

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

<u>Description of package or container</u>
- 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: Green Chilies Farm 01 damage1, Green Chilies 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
- GREEN CHILI RIPENESS CHART (UC DAVIS)

Annex 3: LIST OF INTERVIEWEES

List of CSAM Interviewees for Green chilies and processed chilies. CSAM: January-March 2017.

DATE	LOCATION	NAME	AFFILIATION	PURPOSE
11-Jan-17	NAEB-Kigali	Ben Mugisha	Exporter of Fresh fruits/ Vegetables from Africa	To gather information on chili harvesting period and chili farm location
11-Jan-17	NAEB-Kigali	Charles Wasuwa	Pack-house logistic/ Vegetables from Africa	CSA Questionnaire interview
3-Feb-17	Nyanza District	Habimana Jean Baptiste	Agronomist in Chili farms	CSA Questionnaire interview
3-Feb-17	Nyanza District	Nzabamwita Jean Baptiste	Chili farmer	CSA Questionnaire interview and data collection
3-Feb-17	Nyanza District	SindikubwaboPocien	Chili farmer	CSA Questionnaire and data collection
8-Feb-17	Nyanza District	Karangwa Eugene	Chili farmer	CSA Questionnaire and data collection
8-Feb-17	Nyanza District	Nzeyimana Antoine	Chili farmer	CSA Questionnaire and data collection
11-Feb-17	Kigali	Noel Valentin Mulinda	Postharvest specialist	CSA Questionnaire
28-Feb-17	Rulindo District	Sina Gerard	Chili processor	CSA Questionnaire interview
28-Feb-17	Nyarugenge District	Vuningoma Petit	Chili processor	CSA Questionnaire interview
3-Mar-17	Kicukiro District	Furaha Pascal	Dried bird eye chili exporter	CSA Questionnaire interview

ANNEX 4: SITES INCLUDED IN THE CSAM CROP STUDY

DISTRICTS:
Kigali
Nyanza
Rulindo
Nyarugenge
Kicukiro

CHILI DATA COLLECTION GPS COORDINATES

DATE	LOCATION	FARM, PACKINGHOUSE, PROCESSING PLACE	GPS COORDINATES
3-Feb-17	Nyanza District	Farm 01	02°21'33".34"S 29°41'25.19"E
3-Feb-17	Nyanza District	Farm 02	02°21'27.95"S 29°41'29.18"E
3-Feb-17	Nyanza District	Farm 03	02°22'22.85"S 29°40'58.97"E
8-Feb-17	Nyanza District	Farm 04	02°21'48".39"S 29°41'23.88"E
8-Feb-17	Nyanza District	Farm 05	02°21'34.67"S 29°41'14.59"E
8-Feb-17	Nyanza District	Farm 06	02°22'25.50"S 29°40'46.87"E
9-Feb-17	Kigali	NAEB packinghouse	
28-Feb-17	Rulindo District	Chili oil processor (Nyirangarama ltd)	01°39'46.83"S 29°53'13.84"E
28-Feb-17	Nyarugenge District	Chili oil processor (Treasure ltd)	1°56'50.3"S 30°02'58.4"E
3-Mar-17	Kicukiro District	Dried bird eye exporter (Furaha Pascal)	02°08'08.29"S 30°02'50.05"E

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	ANS	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_2P_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	0.18
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: ____________

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			

TOMATOES Worksheet
Code: Farm____

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 three	Increase	Decreas	no
Have you had sufficient access to pesticides and fertilizers?	Yes	No	N/A

List other notes and descriptions here

TOMATOES Worksheet
Code: Farm____