2019

"Post-harvest Food Loss and Waste in the Nutritional Value Chains of Bush Beans and Nightshade in Uganda"

Klara Strecker
i6097899
k.strecker@student.maastrichtuniversity.nl

Maastricht University
International Centre for Integrated assessment and Sustainable development (ICIS)

Master in Sustainability Science and Policy
SSP3021 (15 ECTS)
Words: 21431

Supervisors: 1st Verena Bitzer
2nd Froukje Kruijssen

Maastricht, 17.08.2019

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My Master thesis is an original result of my own work and does not include the work of others except in the case of direct and indirect quotes that are recognizable as such.

Maastricht, 17th of August 2019

K. Strecker

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List of Abbreviations

BB	Bush Beans
EaTSANE	Education and Training for Sustainable Agriculture and Nutrition in East Africa
FAO	Food and Agricultural Organisation of the United Nations
FGD	Focus Group Discussion
IFAD	International Fund for Agricultural Development
IFLAM	Informal Food (Fish) Loss Assessment Method
kg	Kilogram
KII	Key Informant Interview
km	Kilometre
LT	Load Tracking
m	Meter
N	Nightshade
NAADS	National Agricultural Advisory Services
NRC	United States National Research Council
NSVC	Nutrition Sensitive Value Chain
PHLW	Post-Harvest Loss and Waste
ProNIVA	Promotions of neglected indigenous leafy and legume vegetable crops for nutritional health in eastern and southern Africa
SDG	Sustainable Development Goal
SSI	Semi-Structures Interview
SSA	Sub-Saharan Africa
UBOS	Ugandan Bureau of Statistics
VC	Value Chain
WFP	World Food Programme
QLAM	Questionnaire Loss Assessment Methods

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Abstract

One third of all food produced globally is lost or wasted before consumption. Meanwhile, large segments of the world population suffer from malnourishment, particularly in Sub-Sharan countries such as Uganda. Poor post-harvest handling is a major contributor to food losses in these countries. To increase the productivity of local value chains and increase nutrition, food losses, particularly those of nutrient dense crops such as African nightshade and bush beans, need to be reduced. If handled properly post-harvest, these crops can significantly increase the nutrient content of local diets.

To that end, this research identifies loss hotspots, their causes and effects throughout the nutrition sensitive value chains of nightshade and bush beans, and potential solutions to address them. Primary data collected within the framework of the Informal Food Loss Assessment Method, combined with secondary data from a variety of interviews and focus group discussions allows an analysis of physical, economic, quality, and nutritional losses throughout the value chains of both crops. Bush beans experience more severe physical and overall economic losses, while nightshade is much more sensitive to nutritional losses and to a higher magnitude of quality reductions. A strong combination of product and process improvements is needed to tackle these challenges.

Key words: food loss and waste; value chains; Sub-Saharan Africa; loss hotpots; nutritional, physical, quality, economic loss; IFLAM.

1. Introduction

According to the Food and Agricultural Organisation of the United Nations (FAO), around one third of all food produced globally is lost, immensely decreasing the general productivity of our food system (FAO, 2019a; Schuster & Torero, 2016, p. 24). These losses occur at many different stages of the food value chain (VC), such as production, post-harvest, and distribution (Schuster & Torero, 2016, p. 23). At the same time, one in nine people today—around 815 million—are malnourished, (United Nations, 2015a). An estimated 98% of those people live in developing countries, particularly in Sub-Saharan Africa (SSA), where the problem of malnourishment expands with the population growth rate of up to 2.5% (Jones, Bryce, Vink, & Behar, 2015, p. 3; Ojiewo et al., 2015, p. 187). The large amounts of food lost annually in SSA alone could potentially satisfy the caloric requirements of up to 48 million people (Affognon, Mutungi, Sanginga, & Borgemeister, 2015, p. 49). Consequently, changes to current post-harvest handling practices could reduce this immense food loss and help to lessen the global problem of malnutrition.

Food loss and waste have consequences broader than malnutrition alone. They reduce overall productivity of the global food system, decreasing producer income and increasing producer costs. This can create economic costs of up to $750 million—a burden frequently carried by the poor (Li et al., 2017; Schuster & Torero, 2016). Therefore, post-harvest loss and waste (PHLW) has a social consequence, decreasing people's health, and an economic one, impacting incomes and increasing poverty. A further consequence is environmental: up to one quarter of water, land and fertiliser used for crop production is associated with food waste (FAO, 2011; Shafiee-Jood & Ximing, 2016). Hence, 30% of all agricultural land is used to produce food that is wasted, causing 8% of global greenhouse gas emissions, so that "if food waste were a country it would be the third biggest GHGs emitter after China and the US" (Jones et al., 2015, p. 8; Li et al., 2017, p. 6618). Food loss and waste are thus inherent challenges to sustainability and have recently gained global attention in developed and developing countries: The United Nations included the topic in target 12.3 of its Sustainable Development Goals (SDGs), aiming for halving per capita food loss and waste by 2030 (United Nations, 2015b). Halving post-harvest losses by 2025 is also one of the commitments of the African Union's Malabo Declaration in 2014 (Li et al., 2017, p. 6618).

Despite the prevalence of these issues, there is little coherence in research being done on the topic of food loss and waste. Successful interventions aiming to reduce PHLW remain rare, and data on the matter, particularly in SSA, is fragmented and unreliable (Affognon et al., 2015). Most research on PHLW still focuses on developed countries and the retail and consumer level of the value chain (Li et al., 2017, p. 6619). Studies on developing countries and relevant post-harvest stages of the VC are far rarer. This body of work suffers from problems such as non-uniform measurement for occurrence of food losses; narrow focus on reasons for PHLW occurrence, namely storage problems and insect infestations; and lack of variety of crops studied, which are mostly grains and cereals. These studies neglect other relevant factors that play a role on a local level, such as socioeconomic dynamics that impact the handling of crops.

The quantities of food lost in developing and industrialised countries is similar (FAO, 2011, 2019a). The reasons for food loss are different, however: in developing countries 40% of the waste occurs during post-harvest and processing stages, while in industrialised countries it occurs mostly at consumer level. Hence, expanding the scope of food loss research to understand the variety of underlying reasons for it may provide vital information for reducing malnutrition and other problems endemic to developing countries. One area of interest is Uganda, where losses are rather high at smallholder level. Indeed, the issue has recently gained the attention of Ugandan and international politicians. In May 2019, a *National Strategy for Post-harvest Loss Reduction in Grains* was developed to counteract immense food losses negatively impacting Uganda's economy (FAO, 2019b). This initiative is supported by the FAO, the World Food Programme (WFP), and the International Fund for Agricultural Development (IFAD), and it focuses on the reduction of losses in grains' and pulses' VCs in Uganda. While this programme primarily focuses on the impact of losses on economic productivity, it also focuses on ensuring food security.

To date, many projects in SSA have concentrated on increasing the nutritional value of local diets in addition to reducing food losses. One way of doing so is to focus on the production of nutrient-dense crops such as African nightshade and bush beans. Nightshade is an indigenous African vegetable whose production has been largely overshadowed by the introduction of western crops through colonial powers (Cernansky, 2015). Nevertheless, such indigenous crops have increasingly gained momentum at local markets and in research due to their richness in vitamins, iron, protein, and a variety of other nutrients; their being more resistant to drought; and their abilities to adapt to the local environment and climate (Bioversity International, 2015; Cernansky, 2015; Horticulture Innovation Lab, 2011; Horticulture Innvoation Lab, 2011). An expert panel of the United States' National Research Council (NRC) found that local crops have great potential to increase food security and deserve more focus in research (Cernansky, 2015).

While nightshade farming is less widespread, bush beans are some of the most-produced crops in Eastern Africa (Wortmann, Eledu, David, & Singh, 1999). Like nightshade, they are a major component of smallholder agriculture in Uganda, and fall under the same category of nutrient-dense crops (David, Kirkby, & Kasozi, 2000). Bush beans are a crucial part of the Ugandan diet because, as the 'meat of the poor', they are the second-most important source of protein for locals (Pachico, 1993). Besides, vegetables and fruit generally have the highest spillage rate of around 50%, which make them an important focus point of any PHLW analysis (FAO, 2011, 2019a). Bush beans, on the one hand, can be dried and stored for a long period of time, while nightshade, on the other hand, is perishable. Both are crucial sources of nutrients. A comparative analysis of these crops, therefore, offers an interesting case study.

This masters research focuses on the understanding of the extent and causes of PHLW of two nutrient-dense crops in Uganda, and potential options for its reduction. As one of the main agricultural areas in Uganda, Kapchorwa served as the primary study site for this research. In this rural area with high agricultural potential, 48% of the children aged 6 to 59 months suffer from anaemia (Uganda Bureau of Statistics (UBOS) and ICF, 2018, p. 201). While this is sometimes caused by malaria, it is also commonly caused by deficiencies of iron and other nutrients. Additionally, Kapchorwa is the area with the second-most stunted and third-most undernourished children under five in Uganda (Uganda Bureau of Statistics (UBOS) and ICF, 2018, p. 206). Lack of access to nutritional food is a significant contributor to these dangerous health problems. The combination of the nutritional circumstances in Kapchorwa with the high PHLW make it an interesting area for a case study. Within this context this research aims at answering the following research question.

> "*What are relevant post-harvest loss and waste hotspots, and how can post-harvest loss and waste throughout the value chains for nightshade and bush beans at smallholder farms in Uganda be decreased?"*

This research question is divided into several sub-questions:

1. *Where does post-harvest loss and waste occur in bush bean and nightshade value chains?*
2. *What are the causes and effects of post-harvest loss and waste throughout the value chains of nightshade and bush beans?*
3. *What kinds of interventions could be suitable to reduce post-harvest loss and waste for smallholder farms in Uganda?*

In order to tackle this research question, PHLW analysis is used as theoretical framework within the context of a nutrition sensitive value chain (NSVC) analysis. A VC approach is a useful tool for understanding complex food systems and making them more efficient and nutrition-sensitive through strategic interventions at different VC stages (Peña & Garrett, 2018, p. 14). A variety of different research projects have employed this approach to enable coordination of actors and actions across sectors to address malnutrition (Coote, 2011; C. Hawkes, 2009; Corinna Hawkes & Ruel, 2012; Mazur, 2011).

For the PHLW analysis, a common framework for fish loss assessment is applied to food loss, namely the Informal Fish Loss Assessment Method used as the Informal Food Loss Assessment Method (IFLAM) in this case (Diei-Ouadi & Mgawe, 2011; Ward, 2000; Ward & Jeffries, 2000). This method generates general qualitative and indicative quantitative PHLW data, which has proven helpful in understanding and measuring local losses in a variety of field studies in Africa and Asia (Diei-Ouadi & Mgawe, 2011, p. 2). Particularly in cases such as Uganda, where the existence of losses in known, but the reasons for and levels of PHLW and possible solutions remain unclear, the IFLAM generates deeper understanding within the local context (Ward & Jeffries, 2000, p. 10). Moreover, IFLAM creates data on indicative losses, reasons for such losses and their relative importance, and ideas for loss reductions (Ward & Jeffries, 2000, p. 16). Thus, IFLAM appears most suitable for this case study as it primarily generates a general understanding of the local situations, which is needed before precise measurements can be made.

1.1. Aims and Objectives of this Research

The main aim of this research is an in-depth PHLW analysis within smallholder agriculture and the VC to gain a better understanding of the levels and reasons for food losses in nutrition-sensitive value chains in Uganda. This is based on qualitative and indicative quantitative data on losses which provide insight into possible interventions at different levels. Generally, helping the marketing and establishment of strong networks across the project field supports the development of a stable, nutritious, and local food system (Peña & Garrett, 2018). As losses mostly occur in earlier stages of the VC in developing countries, an analysis of post-harvest techniques of farmers enables targeted support to reduce PHLW. Therefore, this research looks at harvesting techniques, post-harvest handling, marketing and consumption technique to assess challenges and identify loss hotspots. This way, the problem of PHLW in Uganda can be identified clearly and first recommendations for improvements can be made.

Due to the lack of existing research in the field, this thesis is highly relevant for studying PHLW on a local level and, hence, for creating support to face the global crisis of hunger (Affognon et al., 2015). As Jones et al. (2015, p. 27) aptly put it, "[post-harvest loss] reduction interventions provide a unique opportunity to not only address food losses, but also positively impact the lives of [shareholder farmers], other value chain actors and society at large; they improve incomes, reduce toxicity of foods, create greater nutritional diversity and improve efficiency of natural resource usage".

Moreover, as this research is part of the larger research project on Education and Training for Sustainable Agriculture and Nutrition in East Africa (EaTSANE), it aims to support this project with its findings. One of the steps of the EaTSANE project is the set-up of VC platforms for local action learning and focus group discussions (EaTSANE, 2017). These VC platforms bring together relevant stakeholders and aim to develop interventions that increase supply, demand, and nutritional value. Consequently, another practical aim of this master thesis is to create a stepping stone for the set-up and work of these platforms and give specific recommendations on possible VC interventions to decrease PHLW.

To answer the main research question as well as the sub-questions and to meet all objectives, this thesis is divided into five main sections. The first entails a literature review, introducing general food waste and loss terminology and research on the topic in SSA. Besides common reasons for PHLW along the VC, interventions are presented. The analytical framework, methodology, and the research site are introduced in the second section. The third section presents primary results. The focus here lies on answering sub-questions one and two, as loss hotpots along the VC stages and main causes and effects are studied. This is followed by an detailed discussion in the fourth section: physical, economic, and nutritional losses of both crops are comparatively analysed to answer sub-question two, then possible interventions suitable for the case of Kapchorwa are presented to answer sub-question three. The last section concludes and reflects on the research, ending with a set of suggestions for possible future research directions.

2. Literature Review

2.1. Food Loss and Waste Terminology

There is plenty of literature on the topic of food loss and waste, and most of it targets the same points of criticism. Frequently, reliable data are missing due to a lack of coherent definitions and measurements, and systems boundaries are not specified. Much of the literature makes a distinction between food waste and food loss. Food waste is commonly seen as occurring in the later stages of the VC, namely the consumer and retailer level, and is defined as “deliberately discarded food that is fit for human consumption” (Schuster & Torero, 2016, p. 25; Shafiee-Jood & Ximing, 2016, p. 8433). Food loss, on the other hand, refers to spoilage during the earlier stages of the supply chain, and is specifically defined as “unintentional reductions in food quantity or quality before consumption, including postharvest losses” (Schuster & Torero, 2016, p. 25). Food loss is much more prevalent in developing countries such as Uganda, where food waste at a consumer level makes up roughly 5% of total loss and waste, and the remaining 95% are losses occurring during earlier stages of the value chain (FAO, 2011; Jones et al., 2015). However, much literature uses food loss and waste interchangeably, and defines both as “the loss of edible food material” (Balaji & Arshinder, 2016, p. 153; Chaboud, 2017, p. 11165). Indeed, the lack of coherence in definitions can make the distinction difficult. Nonetheless, in Uganda food wasted by consumers and food lost beforehand can be distinguished clearly so that the terms loss and waste are used distinctively. From here forward, no distinction is made between food that is meant for human consumption and food that is not, as this distinction is not relevant for this research. The focus lies on overall post-harvest losses, as bush beans and nightshade are both food crops used primarily for human consumption.

Distinctions are, however, made between different types of food loss, namely physical, economic, and nutritional (Diei-Ouadi & Mgawe, 2011; Ward & Jeffries, 2000). Physical losses are made up of food that is unused and therefore lost entirely. Economic losses comprise the monetary value of food lost due to quality deterioration or market forces impacting the demand or supply of a good. Nutritional losses comprise the loss of micronutrients in food throughout all stages of the VC. Closely related to nutritional and economic losses are losses in quality, which commonly lead to reductions of nutritional value or increased food security risks. To increase nutrition and decrease hunger it is crucial to find suitable interventions for all types of losses (Peña & Garrett, 2018). Hence, this thesis acknowledges the importance of all three kinds of losses and studies them individually.

Much research has reviewed food loss and waste literature and found the common, previously-mentioned shortcomings. Attempts have been made to create a coherent framework that could be applied universally to describe them (Chaboud, 2017; Li et al., 2017; Lipinski & Robertson, 2017; Swannell, Falconer Hall, Tay, & Quested, 2019). Nevertheless, variety in methodology still prevails. On the one hand, researchers have frequently employed quantitative approaches using returns of investment as measurements (Jones et al., 2015; Oduol et al., 2017). On the other hand, differing qualitative methods are often used for case studies (Beausang, Hall, & Toma, 2017;

Chaboud, 2017). Leaving aside the varied methodology, case studies from India, Japan, Scotland, Switzerland, and several African countries have come up with a set of reasons for the occurrence of PHLW, which are described in the next section (Balaji & Arshinder, 2016; Barco et al., 2019; Beausang et al., 2017; Beretta, Stucki, & Hellweg, 2017; Chaboud, 2017; Coote, 2011; FAO, 2017; Gogo, Opiyo, Ulrichs, & Huyskens-Keil, 2017; Tomlins et al., 2016).

2.2. PHLW along the VC: Reasons and Interventions

Different researchers employ slight variations of the VC approach, but commonly there are five stages in the chain, as shown in Figure 1 (Schuster & Torero, 2016, p. 24).

Figure 1 Value Chain Stages

Already during the production stage a number of factors play a role in food loss: unsuitable harvesting times can lead to over-maturity and hence spoilage of food, and weather patterns can rush or postpone harvesting activities. Moreover, inadequately performed field sorting activities can lead to already-harvested, high-quality crops being left on the field, and therefore going to waste. Poor handling techniques and lack of suitable storage facilities can, particularly in developing countries, lead to significant losses (Balaji & Arshinder, 2016; Beausang et al., 2017; FAO, 2011; Gogo et al., 2017; Jones et al., 2015; Oduol et al., 2016; Shafiee-Jood & Ximing, 2016). Commonly, smallholder farmers have no cooling facilities or other elaborate storage facilities. Therefore, goods are frequently stored in houses without proper protection, making them vulnerable to pests and fungal growth, which is one of the most prominent food loss causes. Unfavourable weather conditions play an important role at this stage as well, because they can impede the important drying process—especially when proper drying facilities are lacking. A problem that cuts across most of these steps is that VC actors are often insufficiently trained in activities such as effective handling or stacking or lack the incentives or resources to do so. Said actors thereafter fail to use proper methods and packaging technology, resulting in defective end products and another source of potential food loss. Distribution and retailing pose yet more challenges, particularly in developing countries where infrastructure is not yet built. The lack of market hygiene, proper distribution and cooling systems, and market management make food distribution difficult. The poor quality of road infrastructure and transportation pose additional challenges in SSA.

Table 1 Reasons for PHLW in VC (Affognon et al., 2015; Balaji & Arshinder, 2016; FAO, 2011; Gogo et al., 2017; Jones et al., 2015; Oduol et al., 2016; Schuster & Torero, 2016; Shafiee-Jood & Ximing, 2016; Timmermans et al., 2014)

VC stage	**Reasons**
Production	Harvest timing, overmaturity
	Weather conditions during harvest
	Inadequate field sorting
	Harvest crop left on field
	Damage/spillage
Postproduction on Farm	Lack of drying facilities
	Weather conditions during drying
	Lack of storage facilities (cooling)
	Spillage/ Degradation
Processing	Pest damage, spoilage, fungal growth
	Poor training in handling & stacking
	Lack of processing facilities & methods
	Defective end products due to processing
	Inadequate packaging protocols & technology
Distribution	Lack of proper logistical management
	Lack of cooling system
	Poor logistics infrastructure/ transportation
	Poor market hygiene
	Excess supply
	Spoilage/ spillage
Consumption	Excess purchase or pool purchase
	Poor storage at home
	Bad quality of end product
	Confusion over understanding labelling
	Simply discarding food
Overall VC	Lack of coordination among placers
	Lack of communication among members
	Lack of stringent inventory measures
	Ineffective demand management
	Large number of intermediaries

Even after transportation, a variety of reasons cause consumers themselves to waste food. Many simply discard it, and often would not if not for inadequate knowledge of food labelling, or excess purchases. Such reasons likely predominate in developed countries. Poor storage at home or bad food quality are more likely reasons for food waste in developing countries. A few reasons for PHLW cut across the entire value chain and are more related to the general characteristics of the agricultural system. Poor communication and coordination between a large number of intermediaries can decrease the overall efficiency of the systems. Besides, ineffective demand management can play an important role by causing surplus of certain goods that are subsequently wasted. Altogether these reasons can be causes of large numbers of PHLW. Table 1 summarises all reasons for PHLW separated into different VC stages, as they were mentioned in previous literature (Affognon et al., 2015; Balaji & Arshinder, 2016; Gogo et al., 2017; Schuster & Torero, 2016; Shafiee-Jood & Ximing, 2016; Timmermans, Ambuko, Belik, & Huang, 2014).

Research on value chains in Uganda specifically has identified a few challenges that appeared specific to the region (Oduol et al., 2017; Oduol et al., 2016). The market system in Kapchorwa is disorganised and unstructured, resulting in several issues: There are rather high losses of perishable commodities due to insufficient storage facilities and post-harvest handling equipment, bad road quality during transportation, and weather—agricultural success in Kapchorwa is highly rain-dependent. Overall, the agricultural system would benefit from an expansion of business channels beyond local traders, and better access to business development services for cash crops.

A number of PHLW-reduction interventions have been generated over time to combat these challenges (see Table 2) (Jones et al., 2015; Shafiee-Jood & Ximing, 2016). Some of them aim to refine the product by, for example, improving storage and handling techniques and facilities (Jones et al., 2015). Others focus on adding value to the product by introducing further processing or cooling techniques. Another set of solutions is process-oriented and aims to improve general supply chain processes and interactions. Many solutions are also connected to technological information and improvement of the information infrastructure of the area to enable more foresighted agricultural practices. The suitable solutions to PHLW challenges in Kapchorwa are elaborated on in the fourth section of this paper on interventions.

Table 2 Interventions for PHLW Reduction (Jones et al., 2015; Shafiee-Jood & Ximing, 2016)

VC Stage	Interventions
Production	Information tools (weather & market forecast)
	Growtainers
Postproduction on Farm	Access to efficient storage
	Drying facilities
	Temperature controls
	Monitoring tools (physical, biochemical sensors)
	Heavy moulded plastic containers
	Gum Arabic coating
	ZeroFly bags
	Liquid air refrigeration: Cold storage/ individual quick freezing
	Metal silos
	Low energy cooling
	Mobile/ solar drying
Processing	Mobile processing units
	Graters and pressers
Distribution	Expanding & upgrading infrastructure
	Collection centres
	Warehouse receipts systems
	Contract farming
	Direct sourcing
Consumption	-
Overall VC	Education& community based intervention
	Communication between VS actors
	Supply chain technology platforms

2.3. PHLW in SSA

The focus of PHLW in SSA has commonly been on grain, and has only recently been expanded to include tubers, roots, and fresh fruits and vegetables. Fruits and vegetables have the highest losses in SSA—up to 50%— and the lowest amount of research performed on them (Chaboud, 2017; FAO, 2011; Jones et al., 2015). These crops' health benefits make them key components of nutritious diets, so it is of great significance to reduce losses and enable stronger incorporation into local diets (Ojiewo et al., 2015, p. 187). Particularly in Kenya, researchers have increasingly focused on studying the losses and nutritional benefits of African indigenous fruits, legumes, and vegetables such as African nightshade, finger millet, mangoes, cabbage, beans, and tomatoes (Affognon et al., 2015; FAO, 2017; Gogo et al., 2017; Handschuch & Wollni, 2013; Horticulture Innovation Lab, 2011;

Horticulture Innvoation Lab, 2011; Ojiewo et al., 2015; Ronner et al., 2018). The reduction of losses and increased "vegetable and legume production and consumption are a potent mechanism for small scale, disadvantaged farmers to obtain the required nutrients in their diets and to generate much needed income through trade" in SSA (Ojiewo et al., 2015, p. 187). Hence, fruits, legumes, and vegetables are important crops to focus on because of their often major losses, yet high nutritional potential to improve food security.

Around 75% of the population in SSA works in the agricultural sector, 80% of whom are smallholder farmers (Jones et al., 2015, p. 7). Interventions to better regulate that sector could therefore have immense impact on the economic development food security of the region. Shifting towards a more specialised production system which focuses on nutrient-dense crops has proven to be beneficial (Handschuch & Wollni, 2013). Farmers commonly focus only on cultivating cash crops such as coffee or cotton, which have high income potential. However, these carry a rather high investment risk due to high input costs and market price volatility. Crops such as finger millet and African nightshade, in contrast, have high nutritional value, face little price volatility, and adapt well to local agro-ecological conditions. This makes them powerful goods on SSA's markets. A number of projects, such as Promotions of Neglected Indigenous Leafy and Legume Vegetable Crops for Nutritional Health in Eastern and Southern Africa (ProNIVA), have focused on the promotion of such nutrient-dense crops in SSA (Ojiewo et al., 2015).

2.4. African Nightshade & Bush Beans

Consequently, the focus on goods such as African nightshade (Solanum scabrum) and field bush beans (Phaseolus vulgaris) is particularly interesting. African nightshade is "rich in pro-vitamin A and vitamin C, several mineral micronutrients, health-promoting phytochemicals with antioxidant, antibiotic and anticancer properties, and other nutraceuticals" (Ojiewo et al., 2015, p. 194). However, due to the high perishability of this green, leafy vegetable, it is prone to deterioration, and around half of it is lost before consumption (Gogo et al., 2017). Beans are generally extremely high in protein, iron and carbohydrates. FAO states that "improving and diversifying agricultural production, notably with vegetables and legumes, coupled with education on healthy nutrition, good eating habits, food preparation, and safe handling are effective strategies for overcoming malnutrition and chronic diet-related diseases such as excess weight and obesity, diabetes, hypertension, and cardiovascular diseases" (FAO, 2007; Ojiewo et al., 2015, p. 188).

In the past, indigenous African vegetables were not very prevalent on African markets because they were not promoted by seed companies (Cernansky, 2015). Crops introduced by colonial powers enjoyed much more popularity as indigenous African vegetables were seen as less prestigious so that preparation techniques were lost over time and needed to be actively spread again. Due to increasing promotional activities by several NGOs and research institutes the demand for nightshade has been increasing in SSA (Ojiewo et al., 2015). It used to grow mainly as a weed around people's houses. Nowadays nightshade can even be found in bigger supermarkets in cities such as Nairobi

(Cernansky, 2015). Plus, more variations of nightshade are being developed, making them more economically feasible. Still, nightshade farming is exclusively done by women in Uganda, as it is perceived as a female crop.

Research on nightshade in Kenya has shown that particularly for this crop, nutritional, quantitative, and economic losses throughout the supply chain are severe (Gogo et al., 2017, p. 39). Identified reasons for these post-harvest losses are the “lack of certified seed varieties, unfavourable weather, inadequate post-harvest handling practices and technologies as well as insect pest and diseases” (Gogo et al., 2017, p. 39). These problems are very common in developing countries, making them practical areas to target further research on effective intervention techniques to reduce losses. The high nutritional value, variety of health benefits, perishability, and high percentage of losses of nightshade make it a particularly interesting subject of study for this research.

Bush beans are an important income and nutrient source in Eastern Africa, which has the highest bean production is SSA (Wortmann et al., 1999). Uganda is amongst the largest producing countries. Due to the lack of access to animal protein in the area, alternative sources of protein such as beans are crucial. Therefore, beans are some of the most important crops in terms of calories and protein supply, especially for the poorer segments of society in Uganda (David et al., 2000). However, rapid population growth is leading to reduced farm sizes with decreased soil fertility due to unsustainable intensified farming techniques. Poor and rural Ugandans’ dependence on beans is under threat, and this increases the need to reduce losses in the VC.

All parts of the bean plant are suitable for consumption. The leaves serve as a vegetable while the grains are consumed dried or fresh. Even the stalk is used as soda ash, which is a common food additive in Uganda. The focus of this research lies on bush bean grains, as it is the most important part of the plant in terms of nutrition and income. As opposed to nightshade, which is a traditional food crop, bush beans are considered cash crops. Hence, the focus of bush bean production lies predominantly on its commercial value, rather than value for home consumption. Similarly to nightshade, beans are cultivated mostly by women (Wortmann et al., 1999).

African nightshade and bush beans are both crucial sources of nutrients in Uganda, and hence make up significant portions of local diets. Both face a variety of challenges during harvest, post-harvest handling, trading, and consumption, which this paper focuses on specifically. Table 3 sums up their main characteristics for comparison.

Table 3 Main Characteristics of Bush Beans and Nightshade in Comparison

	Bush Beans	***Nightshade***
Food Group	Legumes	Green Leafy Vegetables
Seasonality	2x per year (rainy and dry season)	Mostly rainy season
Maturity	3 months until maturity	Grows for 3 months & can be harvested weekly
Harvest	Uprooting	Handpicking
Post-harvest handling	Drying, threshing, sorting, storing	Washing
Purpose	Cash crop	Food crop
Final product	Fresh, dried	Fresh
Preparation	Boiling and frying	Steaming, boiling and/or frying

3. Analytical Framework

3.1. Informal Food Loss Assessment Method (IFLAM)

To answer the research questions a qualitative micro level approach is employed, focusing on data on specific steps of the NSVC of nightshade and bush beans. The generated data is specified according to the region and context of Uganda. This approach is useful to get insights into the underlying reasons for PHLW and possible preventive measures and interventions to increase nutritional value (Schuster & Torero, 2016). The measurement and quantification of PHLW present challenges, particularly in smallholder farming in developing countries where uniform measurement is lacking. To that end, the IFLAM framework is used to guide the assessment of the PHLW situation in Uganda. While it was designed for the assessment of fish loss, its general assessment steps can be applied to both fish and crops, making it an ideal tool in this research. Quantitative Load Tracking (LT) and the Questionnaire Loss Assessment Methods (QLAM) are other methodological frameworks commonly used for the assessment of fish losses (Diei-Ouadi & Mgawe, 2011; Ward, 2000; Ward & Jeffries, 2000). However, they are usually applied as follow-up methods based on IFLAM, when there is more knowledge on the local loss situation and possible interventions. They both aim at generating quantitative and statistically valid data. As opposed to that IFLAM is the first step in assessing the loss situation and has potential in guiding other further advanced methods, which is why it was chosen for this research.

The aim of this approach is to identify PHLW hotspots based on general estimations rather than precise measurements, as the identification of loss hotspots should help gaining general understanding of the loss situation and the allocation of intervention techniques rather than aiming at the precise documentation of losses (Diei-Ouadi & Mgawe, 2011). The results of an IFLAM-based analysis can be used to inform decision-making directly, or as a basis for more quantitative measurement techniques. This method has proven to be particularly useful in cases where precise data on losses is missing, as it is the case in Kapchorwa (Diei-Ouadi & Mgawe, 2011, p. 13; Ward & Jeffries, 2000, p. 10). Therefore, IFLAM helps to develop a strong general understanding of the location. It employs a participatory approach, focusing on the active involvement of relevant actors who are knowledgeable about the PHLW and farming techniques or who possess indigenous knowledge on the matter (Ward, 2000, p. 1).

Via this approach a variety of aspects surrounding PHLW can be assessed (Diei-Ouadi & Mgawe, 2011, p. 22). Some of the major focus points are the different types of losses that are faced, namely the physical, economic, and nutritional losses and their severity (*sub-question 1*). Changes and seasonal variations of these losses play important roles too. After identifying the losses and their intensities, possible underlying causes can be uncovered (*sub-question 2*). This includes understanding the factors that impact the losses, such as harvesting and handling techniques or equipment. Finding the loss hotspots includes identifying the VC actors that are most impacted and specifying that impact (*sub-question 2*). This goes hand in hand with assessing stakeholders' general perception of the losses. Finally, IFLAM allows insights into possible interventions, including the identification of past interventions and potential future interventions (*sub-question 3).* The individual methods that compose the IFLAM framework are introduced in the methods section.

3.2. Load Tracking

The disadvantages of the IFLAM include that it generates rather weak quantitative data, and it requires strong planning and involvement in the local context. Nonetheless, it is a useful tool to generate first insights, and it serves as a stepping stone for more quantitative approaches later in the process. Still, to overcome the challenge of weak quantitative data generation, IFLAM is combined with the LT method to measure losses. LT is used either for the quantification of losses along the entire VC, or for the measurement of losses during one specific activity (Diei-Ouadi & Mgawe, 2011; Ward, 2000; Ward & Jeffries, 2000). This involves following the crop through each step from harvest until consumption and measuring what has been lost on the way. LT has been employed not only for the quantification of losses in fish VCs, but also for the study of vegetables such as tomatoes. Hence, as opposed to IFLAM, which aims at generally understanding the loss situations, LT is focused on measurement and quantification of losses. To generate statistically relevant results, LT is commonly done on a large scale, and data is analysed based on basic biometric principles. However, "if LT is used without replication and random sampling elements it will provide a qualitative understanding of where and why losses occur", so that it can be used as part of the IFLAM (Ward, 2000, pp. 25, 27). Thus, in this research LT is used on a small scale as a complementary tool to generate more precise measurements of losses. This combined approach allows the identification of loss hotspots and the assessment of causes and effects of bush bean and nightshade losses along the VC *(sub-question 1 and 2)*. Consequently, the employed framework is sufficient for answering the main research question and sub-questions, fulfilling the aim of this study. It generates detailed qualitative and first quantitative data.

3.3. Operationalisation of Losses

3.3.1. Physical Loss

To answer sub-question one, rough measurement techniques are based on practices employed by the IFLAM and LT framework. Physical losses are measured in weight lost from one VC stage to another (Ward & Jeffries, 2000, p. 3). The losses are calculated by subtracting the weight of crops discarded from the starting total weight of the crops. This is done either by weighing the unit of crop at the beginning and end of each state or activity, or by weighing the starting bulk and then collecting and weighing the losses directly.

Nightshade is sold only fresh in Kapchorwa, and commonly measured in bundles of one or two "hands". Hence, weight in kilograms (kg) is not used for this crop, and loss estimates during FGDs and interviews are instead reported in bundles lost. During the LT of nightshade, total beginning weight at harvest can be measured in kg. The following losses are then weighed separately in kg, as the total weight of the nightshade reduces without actual quantity reductions. This observed weight reduction without quantity reduction can be traced back to water, used for washing nightshade after harvest, pouring out of the nightshade with time. Therefore, picking up lost nightshade leaves is a more precise measurement of losses.

For bush beans both approaches can be employed. A combination of measuring beginning and end weight and weighing the losses separately offers more precise results due to cross-checking. Bush beans are sold dried and fresh and commonly measured in kg when dried and occasionally in tins when fresh. However, tins can easily be converted into kg. Both nightshade and bush bean measurements are converted from their measured units, namely bundles and kg, into percentages. This allows simpler comparison between the two crops. The calculation used for this is:

1. *weight of spoiled crop / weight of total crop* ***x*** *100/1* ***= percentage of spoiled crop***

3.3.2. Economic Loss

Economic losses are measured in terms of monetary value, which means that a loss is the deviation from the potential best price of a good with the best quality (Ward & Jeffries, 2000, p. 6). This does not imply a precise quantification but rather an estimate of the lost percentage of revenue that could have been generated, based on information on the usual costs of a high-quality good. Therefore, the calculation of the economic losses gives direct insights into quality losses along the VC. Both food depreciation and loss of whole food can be measured by deviation from best price, which can be obtained for the best quality product at the given time. In this step, the physical loss is transformed into an economic loss to shed light upon the financial aspect of PHLWs. Consequently, the physical loss, calculated in the previous step, is the basis for the assessment of the economic loss in combination with quality reductions. Additional variables that must be known include the best price and the reduced price, e.g. due to lower quality, per bundle or kg of high-quality nightshade or bush beans; the quantity of the crops sold for the reduced price; and the amount of food lost completely. Once all these numbers are known the total economic loss can be calculated. Just like physical loss, economic loss is calculated in percentage to make the crops comparable, as their prices differ. The difference between the total economic loss and the physical loss then makes up the overall quality loss of the crops. Adding up the economic losses of all VC stages makes up the total VC loss, including physical and quality losses. The following set of calculations is to measure the economic losses:

1. *(full price[1] - reduced price)* ***x*** *number of units sold at reduced price* ***= loss in revenue due to quality loss***
2. *number of lost units* ***x*** *full price* ***= loss in revenue due physical loss[2]***
3. *all units* ***x*** *full price* ***= maximum value of food***
4. *loss in revenue due to quality loss* ***+*** *value of physical loss* ***= total financial loss***

[1] full price= best price
[2] physical loss= crops that are lost completely that cannot even be sold for reduced price anymore

5. *total financial loss / maximum value of food* ***x*** *100* ***= total financial loss in %***

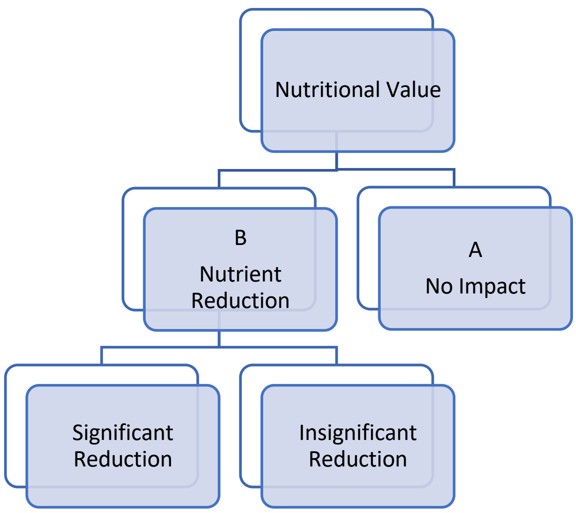
Market forces are another factor that strongly influences the prices of local crops, which also leads to economic losses. During harvest time prices generally go down: as supply increases, profit decreases. However, the economic loss calculation in this case does not include the impact of these changing market dynamics as this requires observation over a longer period capturing the whole market cycle. Due to the limited timeframe of this research this assessment was not sufficiently possible. Consequently, the economic loss calculations predominantly give insights into quality reductions.

3.3.3. Nutritional Loss

The measurement of nutritional losses is merely approximated, because assessing the exact micronutrient losses of crops requires in-depth scientific. Nonetheless, general estimates can be made related to the impact of certain forms of post-harvest handling and preparation on the nutritional value of nightshade and bush beans. For this purpose, the impacts of heat, light, and water exposure on the nutrient content of these crops is studied. Hereby, the focus lies specifically on the impact of drying, soaking, washing, storage, and sun exposure during trading and preparation methods. The impact is separated into two main categories. *Category A* means there is no impact and *Category B* means there is a reduction of nutritional value. The second category can be split into significant and insignificant reductions based on general estimates. Some forms of handling impact the nutrient content of crops but not to a significant extent, which makes them insignificant. This distinction is visualised by Figure 2.

For this assessment the predominant nutrients in bush beans and nightshade need to be known, as well as the common handling and preparation practices. Next, the general impact of these practices on the nutrients is studied to estimate potential nutritional losses.

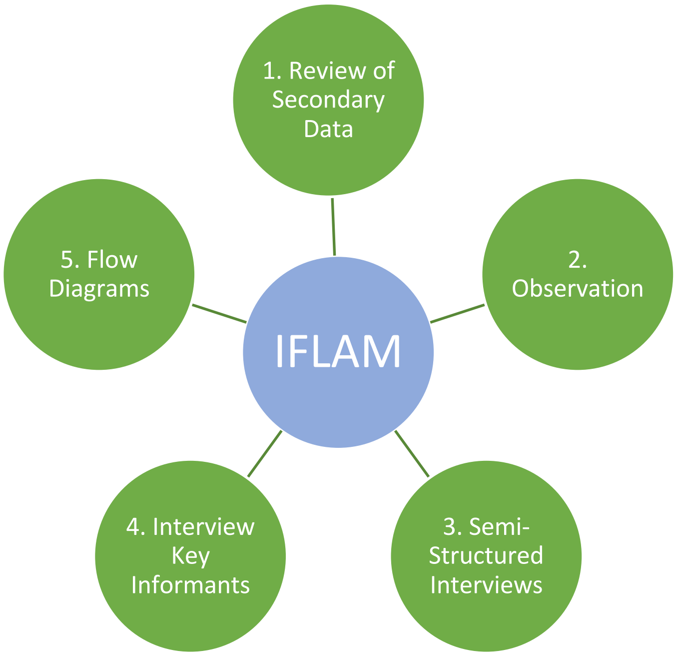
Figure 2 Assessment of Nutritional Loss



4. Methodology

The IFLAM framework is a set of methodological steps designed to gather all needed information for the operationalisation of losses, as shown in Figure 3. This entails a combination of primary and secondary data, which is elaborated on in the following section.

Figure 3 Steps of the IFLAM Framework



4.1. Secondary data

The review of secondary data is the first necessary step (Diei-Ouadi & Mgawe, 2011; Ward, 2000; Ward & Jeffries, 2000). These data consist of an in-depth literature review, including the study of previous case studies dealing with similar situations, and other data generated as part of the EaTSANE project. Interview data from 15 focus group discussions (FGDs), 22 interviews with VC actors dealing with bush beans, and 9 dealing with nightshade, as well as 2 key informant interviews (KIIs) were accessed as part of the previously-generated data of the EaTSANE project. Together these sources provide background on current knowledge and experiences in the field. Based on this, first perceptions of common PHLW hotspots and underlying reason and effects were gained, as well as ideas for possible intervention techniques (see Tables 1 and 2). These findings formed the basis for a three-week field study in Kapchorwa, Uganda, during which a number of interviews and FGDs were conducted and field observations were collected. The literature review and previous case studies were used to develop the interview questions beforehand, so that potential reasons and PHLW hotspots can be confirmed or falsified in the local context. The review of secondary data created the basis to answer all three sub-questions, but was used predominately to answer sub-question three dealing with potential interventions.

4.2. Primary Data

4.2.1. Observations

A three-week field visit to Kapchorwa in June 2019 offered sufficient time to conduct a variety of information-gathering activities to answer the main research question and all three sub-questions. One of these activities was field observations as per step two of the IFLAM framework, which emphasises participatory and development techniques. Individual field observations provide immediate insights into the magnitude of losses and the socio-economic and infrastructural circumstances in Kapchorwa. Indeed, getting an impression of the local dynamics and environment is necessary to understand the unique local VC. Thus, observations are used to complement the interviews and confirm their results and vice versa (Diei-Ouadi & Mgawe, 2011, pp. 28-31). Reflections and documentation of agricultural or storage practices as well as studying of social dynamics form the basis of these field observations.

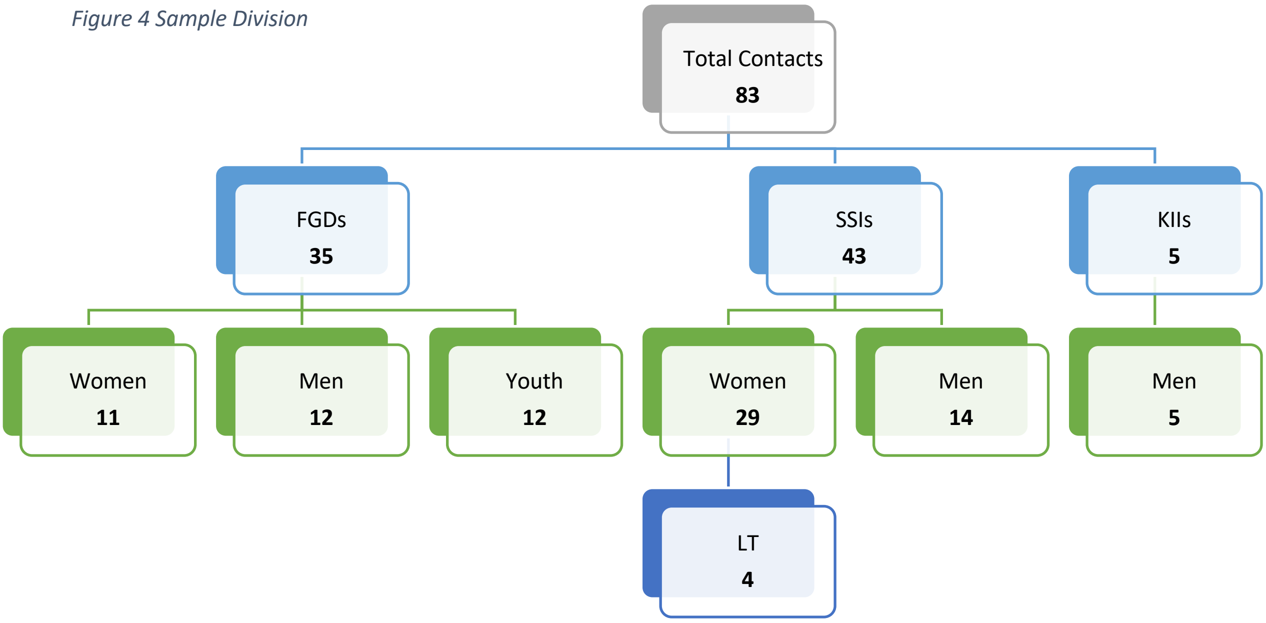
An observation checklist was used to guide the field visit (see appendix). It covers general topics such as hygiene of surroundings and people interacting with crops; storage facilities; measures taken to protect crops from rain, sun, and other contaminators; handling equipment and methods; types of crops sold; general market dynamics and practices; and loss reduction measures. Moreover, in line with the IFLAM framework, a sensory score sheet was used to assess quality of crops as good, poor, or bad (Diei-Ouadi & Mgawe, 2011, p. 49). This score sheet looks at six quality assessment criteria to judge the condition of the crops: insect infestations; discoloration; sun exposure; presence of moulds; breakage/physical damage; and smell (see appendix). For the assessment of quality and nutrition losses, the observations and especially the sensory score sheet play important roles.

4.2.2. Interview Data

During this field visit 83 people were spoken to, of whom 44 were women, 31 men, and 12 youth farmers between the age of 14 and 30. That the number of women exceeded the number of men is unsurprising, as both crops are mostly farmed by women (see Figures 5 and 6). Nightshade is culturally seen as a female crop to be farmed and traded exclusively by women. Bush Beans are mostly farmed by women—even though men contribute occasionally —and are later traded by both men and women de pending on traded quantities.

Moreover, the research activities took place in Kapchorwa town itself and 20 more villages in the area as well as in Kampala. The total number of respondents can be split up into three main activities: Focus Group Discussions (FGDs), Semi-Structured Interviews (SSIs), and Key Informant Interviews (KIIs) (see Figure 4).

Figure 4 Sample Division



4.2.3. Focus Group Discussions

Three FGDs took place during the first week: the first with 12 men, the second with 11 women, and the third with 12 youth farmers both male and female. The three groups were located respectively in the lower, middle, and higher belt to represent all agro-ecological zones of the area. These zones and their retrospective characteristics are elaborated on further in the section introducing the research site. Hence, the FGDs gave insights into all three social groups who work under a variety of environmental conditions. These discussions helped generate primary understanding of the functioning of the nightshade and bush bean VCs in Kapchorwa. They provided a general introduction to PHLW situation in the area and to local key activities, and they helped to identify relevant stakeholders (Diei-Ouadi & Mgawe, 2011, p. 24). In short, they were used to guide the coming interviews. During the FGDs, reasons for losses during harvest, transport, cleaning, drying, sorting, packaging, storage, and consumption were identified via a group process in which all actors wrote down their own challenges and presented them to the group. These findings were then mapped out step-by-step to visualise the reasons for PHLW in each VC stage using a flow diagram. Based on this overview, the group brainstormed possible interventions and reflected on past interventions. The FGDs were an important first step of the field visit because they helped generate a first comprehensive overview of relevant factors to investigate further during the interviews.

4.2.4. Semi-structured interviews

Interviews with VC agents involved in food production, post-harvest handling, trading, and consumption made up the biggest part of the field visit (Peña & Garrett, 2018, p. 56). 43 interviews were conducted, 29 with women and 14 with men, which again is not a surprising gender division due to the aforementioned reasons. The interviews were separated into actors dealing with either one or both studied crops. From the 43 interviewees, 29 were actors of the bush bean VC and 23 of the nightshade VC, while 9 were actors in both. Those actors were roughly split into four categories: farmers; farmers who are also traders; traders; and restaurants. Farmers and traders were also interviewed as consumers, but the restaurants exclusively represented the consumption step of the VC in the reported data. The exact representation of all actors is shown in Figures 5 and 6. Clearly, interviews were conducted with a variety of agents, relevant for all stages to get a broad overview of the functioning of this specific market. Interviewees were mostly identified via snowball sampling, which proved to be efficient in the local village culture. Moreover, distinguishing between men, women, and youth farmers helped to understand the underlying social dynamics of the locality.

Figure 5 Interview Division Bush Beans

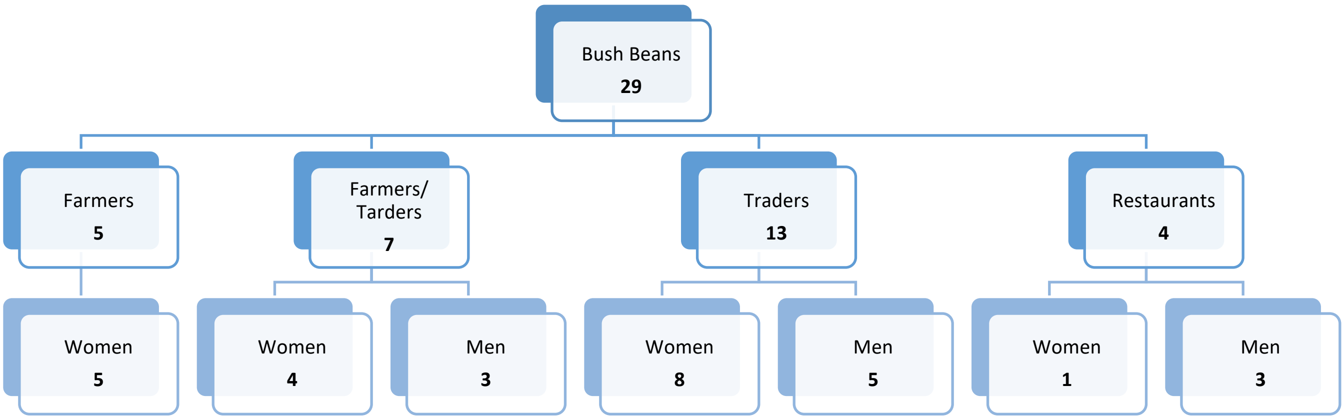
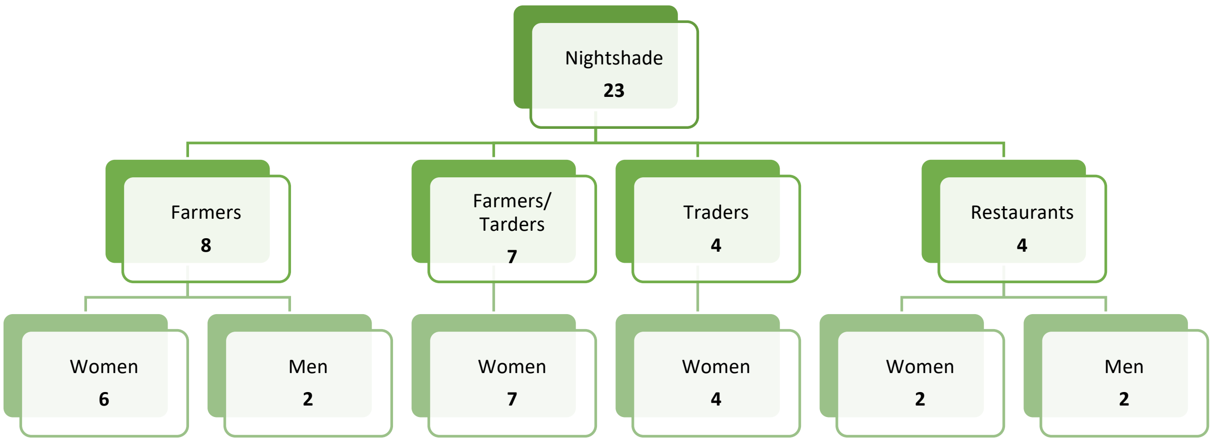


Figure 6 Interview Division Nightshade



Bush bean farming is much more common than nightshade farming, which makes bush bean farmers an easier target group. Bush beans are a cash crop traded commercially, whereas nightshade is a food crop traded on a much smaller scale. Therefore, the number of interviewees that exclusively trade nightshade without farming it is comparatively low. Many farmers farm it for home consumption only, or trade it themselves either at the market or, most commonly, with neighbours who visit their farm. This explains the difference in numbers of traders between the crops. Other than that, the sample is rather similar in terms of representation of VC actors.

The interviews were semi-structured in style because of the language barrier. They were facilitated by a local translator. At times the interviews were fully or partially translated, while some could be conducted entirely in English. SSIs were used to minimise information lost in translation and thereby maximise the reliability of the results. The data derived from the interviews gives insights into the VC, allowing identification of barriers, opportunities, and possible interventions as well as indicative quantitative data on PHLW. To that end, the interview data is coded according to the different actors—namely farmers, traders and consumers—and the three different kinds of losses. Excel is used to capture the interview findings and structure them according to the established categories. For data-analysis purposes, interview findings are compared to identify most-frequently-reoccurring topics pointing towards PHLW hotspots, and to calculate loss estimations. Those findings are checked against possible interventions identified in secondary data, during FDGs, and in interviews.

4.2.5. Key Informant Interviews

KIIs are an important final step of the field visit. Interviews with loss and VC experts help to confirm and cross-check the findings of the SSIs and FGDs (Diei-Ouadi & Mgawe, 2011, p. 38). Not only can they validate findings but they can also give new insights. Key informants play a particularly important role in getting information on possible interventions and their local uptake. Furthermore, they help to generate a deeper understanding of the reasons for and consequences of losses for the local communities. During the field visit five KIIs took place (see Figure 4). Four extensions officers were interviewed as key informants to provide expert knowledge on physical and economic losses as well as past and future interventions. Then, a food scientist from Makerere University was consulted as a key informant to provide expert input for the study of nutritional losses.

4.2.6. Load Tracking

Via LT, a more precise understanding and measurement of the losses throughout the VC and in each of its individual steps could be gained. Several sets of crops were tracked from harvest through cleaning, drying, sorting, packaging, transport, and trading until consumption. The crops were weighed at the beginning and end of the VC and at every step in between. Moreover, losses during transportation were collected and weighed. Overall, four LT sessions complemented the interview and FGD findings (see Figure 4). The entire nightshade VC from harvest to consumption was tracked during three of the four LT sessions. The fourth one looked at specific activities during the post-harvest handling of bush beans, instead of following the entire VC.

Due to a drought during the beginning of the year, the bush bean harvest was delayed. Therefore, tracking of the entire VC was not possible within the time frame of the field visit. Still, towards the end of the research the first beans could be harvested in the lower belts, where crops usually ripen faster due to the more moderate climate. The entire VC of bush beans entails different steps that would take around one week, which exceeded the duration of the field visit. Hence, only individual steps could be tracked, giving less holistic insights compared to the nightshade tracking. Nonetheless, observing the handling of the beans and measuring individual losses still strongly contributed to this research.

4.2.7. Flow Diagrams

Flow diagrams were first used during the FGDs, if possible, to visualise PHLWs and trigger discussions. Based upon a combination of all previous findings advanced flow diagrams were particularly helpful to understand where to target interventions and, thus, to answer sub-question three (Ward & Jeffries, 2000, p. 48). They are a useful tool to show the functioning of the entire VC system and to illustrate interconnections between the stages. For that purpose, the flow diagrams incorporate a set of categories: types and level of losses, affected stakeholder, VC stages and loss hotspots (Diei-Ouadi & Mgawe, 2011, p. 25). This method allowed graphic and coherent demonstration of the final findings.

4.3. The Research Site- Uganda, Kapchorwa

The agricultural sector lies at the core of Uganda's economy, contributing to around 23% of the country's GDP and employing 60% of the population (Kimaiyo et al., 2017, p. 1). Agriculture is dominated by smallholder farmers, who generate profit mainly through farming and crop production. However, dairy livestock; minor trade; selling agroforestry and forest products such as honey and timber; small scale coffee processing by women; and quarrying are alternate activities for profit generation (Oduol et al., 2016, p. vi). In Kapchorwa, a district in eastern Uganda, large parts of the agricultural activities take place. The district is split into eleven sub-counties, namely Kapchorwa town, Kaptanya Kapteret, Chema, Amukol, council Kapchesombe, Tegeres, Sipi, Chepterech, Kawowo, and Kaserem. It is the second most populated district of Uganda, with a population density of 295 to 886 persons per km^2 (Kimaiyo et al., 2017, p. 1).

The natural environment is shaped by the unique ecosystem of Mount Elgon, which can be divided into highland, midland, and lowland parts. A large part of the area, namely the Mount Elgon national park, is protected, but the rest is used for farming. The agro-ecological zones are three as well: the mountains high farmlands with an altitude of 1466 m, Kapchorwa's farming forest with an altitude of 1455 m, and the north-eastern short grass plains with rich clay soils at an altitude of 1093 m (Kimaiyo et al., 2017, p. 5). Climate varies strongly, with inconsistent rainfalls between September and March causing drought and low agricultural performances, and the period from April to August characterized by strong rains causing landslides and soil erosions. This variety in climate poses many challenges for local agriculture.

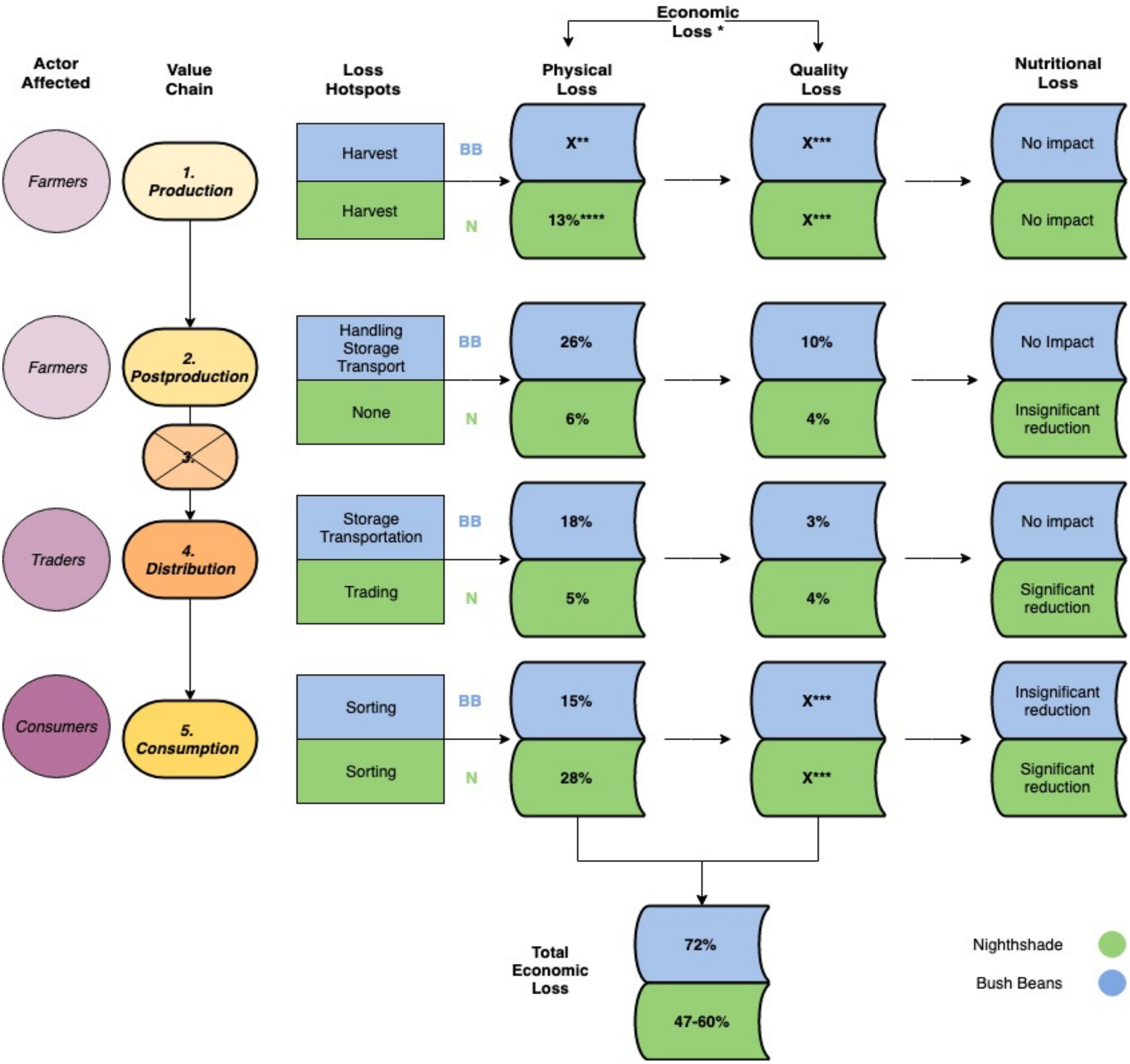
Still, research on food security in the area has shown that almost all households in Kapchorwa have access to a diverse diet, and consume food from a variety of categories such as oils, cereals, sugars, and vegetables (Kimaiyo et al., 2017, pp. x-xi). Nonetheless, the Ugandan Demographics and Health Survey showed that the Kapchorwa area has the second highest number of stunted children, indicating a chronic lack of nutrition. Consequently, lack of nutritious diets—particularly for children—continues to pose a strong challenge to Kapchorwa's population.

Agriculture is the main income-generating activity in the area, and the predominant crops are maize, beans, bananas, and coffee. A variety of farmers groups has been established over the years offering platforms to structure the market for different goods, enabling forms of collective marketing and value additions (Oduol et al., 2016, p. vii). Within these groups individual farmers can come to share ideas, resources, farming practices, and labour force. Generally, there are more female groups than male ones, despite most households being male-headed. However, information flows still lack continuity and efficiency, particularly due to the dissolution of the national agricultural advisory services (NAADS) and limited access to business advisory services (Oduol et al., 2017, p. xii). Lack of information and training are some of the many challenges that this paper elaborates on in the following sections.

5. Results

To fully understand the losses along the VCs of bush beans and nightshade, the analysis follows the different stages from harvest until consumption. However, since the focus of this research lies on post-harvest losses, the production step is briefly touched upon without thorough elaboration. In addition, the processing step is skipped because neither of the two crops goes through proper processing at a processing site. Beans are sold fresh or dried and nightshade is sold fresh, so neither goes through a proper value-adding process. Figure 7 summarises the findings of the entire analysis in a flow diagram. The affected actors; loss hotspots; and physical, financial, nutritional, and overall losses of bush beans and nightshade are presented for each VC stage to generate a broad overview. The following section introduces physical, economic, quality, and nutritional losses during production and postproduction, distribution, and consumption of both crops and clarifies the dynamics presented in the flow diagram. Before looking at the individual stages it is important to note that both VCs are entirely local, which means that they take place fully in the area of Kapchorwa and occasionally neighbouring areas.

Figure 7 Flow Diagram of Loss Estimations according to VC Stages[3]



5.1. Production and Postproduction

The production stage comprises preharvest and harvest activities, such as the use of fertilisers, pesticides, and harvesting techniques (Schuster & Torero, 2016). This research briefly touches upon the harvesting techniques of bush beans and nightshade because farmers continuously stressed their importance for understanding losses and the challenges they face during the entire VC chain.

[3] * Economic Loss = Physical Loss + Quality Loss
*** Production loss of bush beans is included in postproduction loss as they could not be distinguished*
**** Quality Loss is measured is not measured during these stages*
**** *production loss due to pests*

The postproduction stage involves the handling, storage, and transport of crops after harvest (Schuster & Torero, 2016). Handling activities include sorting, cleaning, and drying. This stage is extremely labour intensive for local smallholder farmers and a crucial part of the loss analysis.

5.1.1. Bush Beans

For a variety of reasons, bush beans are some of the most commonly farmed crops in Kapchorwa. According to the local farmers, their quick growth makes them a good source of income and food for home consumption. The beans can be harvested twice per year and only require three months to reach maturity. Some varieties mature all at the same time, while others mature step-by-step, allowing the harvest to be spread out over a couple of days or a week. Most interviewed farmers planted beans on one half to one acre of land while some planted on up to four acres. This brings yields between 100 and 1500 kg of bush beans per harvest. Either way, no matter the scale, bush beans require a lot of hard work.

This crop is harvested via uprooting, which means that the entire plant including roots is pulled out of the soil for harvest. This technique is extremely labour intensive and does not allow for very precise selection of the beans on the field. Many of the farmers report high losses during the harvesting process, and most of them describe it as their loss hotspot, which means that it is the point during their activities where they experience the most losses. Reasons for losses are mostly linked to poor timing of the harvest. If harvesting takes place too late, then two things can cause immense losses: On the one hand, if the beans have been left on the field for too long in dry weather, then they tend to dry to such a degree that the pods pop open, spilling the beans. On the other hand, if the beans have been left on the field for too long in rainy weather, then they will start rotting on the field. This can even happen if the harvest calendar was followed precisely, simply due to the bad luck of excessive amounts of rain during the growing season. Another reason for the harvest losses is a lack of work force to harvest efficiently. Farmers stated that often they cannot afford enough help, so they must leave crops behind on the fields to spoil. Hence, more beans are planted than can realistically be harvested, which is one of the reasons for the challenge of poor harvest timing.

Once all beans are uprooted, they need to be transported to the farmer's home for further handling. Transport poses a huge challenge to farmers after harvest and during the distribution step of the VC. Few farmers' fields were adjacent to their homes—many were between 2 and 10 kilometres (km) away. Larger fields were often located further away, up to 20 km. Even two km can pose a challenge due to bad roads and lack of vehicles. Most farmers carried the harvested beans still in the pods on their heads and walked home for hours. Very few used a motorbike or other vehicle. Sometimes the beans in the pods are put into sacks for transport but most commonly they are piled up and tied together with bags or banana leaves. Consequently, the losses during transport can be significant. The bad roads increase the likelihood of parts of the harvest falling off or leaking out of sacks, and they can even lead to accidents such as falls which cause severe losses. Moreover, during transport the beans are exposed to all kinds of weather conditions. The challenges of harvest can be mirrored during transport in heavy rains, in which exposure can cause the beans to start rotting or germinating, and in intense sun, in which drying causes the beans to spill out of the pods during transport. Therefore, the losses during post-harvest handling depend on good harvest timing. Overall, production and postproduction stages are strongly interlinked for bush beans and can hardly be studied in isolation. Often rotten beans are moved from the fields to farmers' homes for post-harvest handling, so that losses caused by factors on the field are measured as losses in the later stages.

When the beans are transported to the farmers' home a variety of post-harvest handling activities take place on farm. During rainy season the beans still in the pods need to be dried in the sun first so that they can be threshed later to separate beans from pods. During dry season the pods are often dry enough to be threshed right away. For threshing all beans are spread out on the ground or a tarpaulin and beat with a stick, so that the pods open and the beans pour out. After separating the pods and stems from the bean seeds, they are spread out on the floor or tarpaulin in the sun to dry. The time required for the drying process varies depending on the weather conditions. With hot and dry weather beans can be dried within a day, whereas with rain it can take up to one week. Once the beans are dried, they are cleaned of dust and other dirt using the traditional winnowing technique. Some farmers just leave the beans outside and let the wind blow away the dirt, but many use basins for winnowing.

Threshing, sorting, drying, and winnowing are closely-connected activities that offer several opportunities for losses. Generally, losses appear to be more severe when farmers do not have any or enough tarpaulins, a problem which forces them to spread the beans on the ground. Damaged tarpaulins also cause problems. Spillages occur throughout all these activities due to heavy wind, animals eating the crops, or playing children. Farmers mostly have no dedicated, protected places for the handling of crops outside the influence of such external factors. Another major challenge is sudden rains, which necessitate carrying the beans inside. During the constant moving, many beans get lost. Especially without a tarpaulin this can be very difficult so that the beans end up being exposed to water. Hence, rains cause losses due to the dropping of beans as well as the rain exposure, which can cause rotting and germination. Overall, a lack of proper post-harvest handling equipment was observed. Indeed, most farmers had none at all.

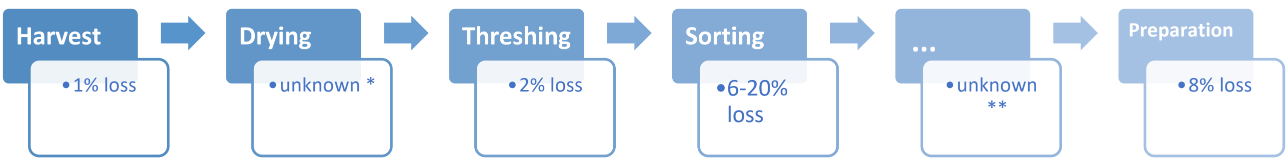
Once the beans are dried properly, they need to be packaged and stored. Some farmers still re-sort the beans before packaging to discard broken or rotten ones and to ensure quality. Others package the beans immediately. Commonly, beans are stored in sacks of around 100 kg on wooden pallets or timber to elevate them from the ground. The elevation is supposed to prevent moisture and pests from entering the sacks from below. Some farmers also put a tarpaulin underneath if they have no access to pallets. It is normal to store the sacks in farmers' homes, because many cannot afford proper storage rooms—especially not the ones who live more remotely. During the storage period of up to three months, farmers frequently suffer losses due to pests. The most common problems are weevils, rats, or termites entering the sacks and causing damage. Other problems include mould and rot which follow improper drying or moisture entering the sacks during the storage period. Pest- or mould-related damages of beans were observed in all local shops to different extents and can lead to complete physical losses and quality reductions.

Farmers made estimates of the amounts of beans they lose during the entire postproduction phase and their loss hotspots. Based on their estimates, transport, handling, and storage all pose a loss hotspot for an equal number of farmers. However, losses during the handling of the crops appear to be more continuous, as storage and transport depend more on external circumstances. The basic handling techniques inevitably lead to some form of spillage, while losses during transport and storage can be severe but do not occur as reliably. Generally, farmers stated that there are always losses during the postproduction stage and that they are much more severe during rainy season. Rain leads to many of the problems that cause physical and quality losses during these stages, as beans are very sensitive to moisture. However, most farmers said that their loss hotspot occurs during harvesting itself, and hence in the production stage of the VC. For farmers selling fresh beans, the losses are much less since they sell them still in the pods and skip most post-harvest handling activities.

Based on farmers estimates, the total **physical loss** for farmers is 26% of the entire yield. Besides the physical losses**, quality losses** of 10% take place leading to a total **economic loss** of 36%. These numbers include the loss during harvest, transport, handling, and storage to show the total impact of losses on farmers. The losses during harvest and post-harvest activities are so strongly interlinked that they are combined in the total loss numbers. Clearly, farmers experience immense losses. Most stated that they are very impacted by the losses, whereas some said that there is an impact, but it does not limit them too much since it is perceived as normal for bean farming.

To validate these findings, some of the postproduction activities were measured during LT. Harvesting, sorting before threshing and after drying, and threshing itself were tracked (see Figure 8). The beans were not too dry, so the harvest loss was minimal (1%), and there was no loss while carrying the crops home from the field for around 15 minutes. Due to the heavy rains many of the beans started germinating and rotting, so they had to be sorted out. The LT session showed a physical loss of 9 to 23% excluding the crops lost during drying. Hence, the measured loss is comparable to the estimated loss of 26% by farmers.

Figure 8 Load Tracking individual VC Steps Bush Beans [4]



[4] * Drying loss was not tracked
**Distribution stage was not tracked

In addition to the physical and quality losses during postproduction, the **nutritional loss** was studied. Based on the KII with a food scientist it was concluded that bush beans experience no nutritional losses during this stage. Protein and iron, the two most important components, are neither heat- nor light-sensitive. Consequently, the sun exposure during all the post-harvest handling activities does not impact them. In Kapchorwa beans are dried by sun exposure so that they are only subject to a maximum temperature of 25 to 30 degrees Celsius that reduces their moisture content to 13,5%. This moisture reduction allows them to be stored for long periods of time without germination or deterioration. The storage itself does not impact the nutritional content of the beans, according to the food scientist. Rain exposure, thus, also does not impact the nutritional build of the beans if they are dried appropriately afterwards. Therefore, bush beans' nutritional build-up shows no sensitivity to postproduction activities in Kapchorwa.

5.1.2. Nightshade

Nightshade production is spreading increasingly amongst farmers in Kapchorwa, especially women. However, according to the interviewees it is still usually farmed on a rather small scale. Most of the women dedicated only around a quarter or half an acre to nightshade farming, which generates an average harvest of around 40 bundles per week. Their motivation to farm this crop was mostly to generate income and food for home consumption.

The traditional harvest technique is picking by hand or with a knife. After the plant has reached a height of around 20 cm, mature leaves can be picked off on a weekly basis. This way new leaves keep growing and the plant can be harvested for up to three months until it gets lignified. Nightshade requires plenty of water, which is why it is mostly planted during the rainy season. A few interviewees who had the needed resources and access to irrigation also planted during the dry season. Most farmers reported major losses of nightshade on the field due to pests. Nightshade was described as particularly sensitive to pests and diseases, especially during the rainy season. During dry season many struggled with low yields and insufficient germination. The harvesting technique itself does not usually lead to losses because careful handpicking is rather precise and prevents unnecessary dropping, compared to the uprooting technique used for bush beans. Instead of harvesting infected nightshade and taking it home like they often do with bush beans, farmers usually leave such sick crops on the field. This way the problems in the production stage do not lead to significant postproduction losses and can be studied separately. This separation was not as clear cut for bush beans. Some interviewees gave estimates of their losses to pests on the field leading to an average **physical harvest loss** of 13%. However, the harvest losses vary greatly and can be severe to the point that the entire yield is lost, which would drive this estimation up significantly.

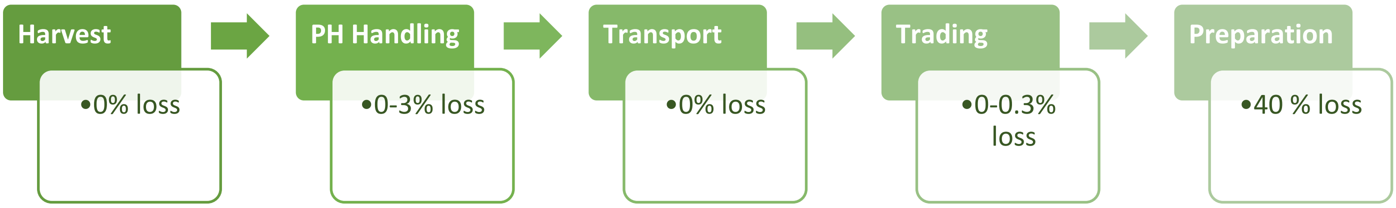
After handpicking, the nightshade was either moved to the farmers' homes or sold to traders and neighbours right on-field. For most farmers, the nightshade field was located within the compound of their home, so that transport did not pose a challenge to them in terms of losses.

Sorting already takes place during the harvesting of nightshade on the field, rather than at home. Plants that suffer from pest infestations are simply left on the field, as they are not of use anymore. Consequently, sorting does not take place again during postproduction. However, commonly the interviewed farmers still clean the nightshade before selling. If it is dry and the leaves are therefore not muddy, some farmers do not even wash them, thereby avoiding potential losses throughout this step as well. Nonetheless, most farmers wash the nightshade with clean water in big basins and leave it in the sun to drip off for a short period of time. According to them, occasionally some leaves fall off during washing, but generally the losses are minimal. Particularly young nightshade rarely loses leaves, while older plants are more prone to losses. The washing is the main source of potential losses in this stage.

Generally, nightshade is not stored, but rather sold directly after harvest so that farmers do not face any storage losses. The responsibility of packaging for transport is often passed on to the traders or consumers who purchase straight from farmers. Some still package the nightshade in big sacks, mostly if they trade it themselves. When asked about their loss hotspot, all interviewed farmers indicated challenges on the field and stated that post-harvest handling usually does not cause significant losses for them. Their biggest challenge are field pests that can ruin entire harvests. During the field visit it was observed that on all fields at least some plants were suffering from pests, confirming farmers' concerns. In summary, farmers stated to be very impacted by the losses due to pests, but not by the minor losses occurring during postproduction.

Based on farmers approximations, the total **physical loss** of nightshade during postproduction is 6%, including losses during transporting, washing and packaging and excluding losses due to pests. **Quality losses** are around 4%, which can mostly be traced back to factors on the field, such as insets and pests, impacting the overall quality of the nightshade (total **economic loss** of 10%). Still, this impact is much less for nightshade compared to bush beans. When including the on-field loss due to pests, the physical losses increase to around 18%. This is the total loss experienced by farmers as they are the actors affected by losses in these two stages. During three LT sessions the losses of nightshade were measured and were observed to be even lower than the farmers had estimated (see Figure 9). No losses could be observed during the handpicking on the field. The fields were within the farmers' compounds so that post-harvest handling involves washing, drying, and packaging, and excludes transport. The observed loss during these activities was between 0 and 3%. Overall, the women were very careful and minimised losses and the nightshade plants were overall in good condition. Since losses mostly occur when dealing with older nightshade plants or the ones affected by pests, observed losses can be lower than estimated in interviews. All the farmers passed the nightshade on to a trader who transported it to town for distribution.

Figure 9 Load Tracking whole VC Nightshade



As nightshade contains many sensitive vitamins, **nutritional losses** are much more prominent than physical and economic ones. Some of its most significant components are vitamin A, which is heat-sensitive and oil-soluble, and large amounts of vitamin C, which is light- and heat-sensitive and water-soluble. This means that light and heat exposure break down the vitamins' chemical structures, leading to losses. The severity of these losses depends on the intensity and duration of light and heat exposure, the texture of the nightshade, and the oxygen inflow. Consequently, many factors play a role, and further research would be required to assess exact losses. However, potential points during handling where nutritional losses could occur can be determined without exact measurement. Firstly, the impact of washing the nightshade after harvest can be assessed. For water-soluble nutrients to be lost there needs to be an open channel in the plant through which vitamins can pass. At the point of washing, the only open channel is the cut end where the branches were cut from the nightshade plant, which would account for only minimal losses. Hence, no significant loss can be caused at this point. Secondly, the nightshade is often left in the sun for a few moments to drip off. However, the duration of sun exposure is not long enough to have a significant impact on the nutritional value. Therefore, the nutritional losses during the postproduction stage are insignificant.

5.2. Distribution

Retail and transportation are key components of the distribution stage (Schuster & Torero, 2016). Kapchorwa traders, as main actors of this stage, engage in a broader set of activities, including sorting, drying and storing.

5.2.1. Bush Beans

Beans are cash crops and hence traded on a regular basis. All interviewees who sold dried beans did so in permanent shops based at the local market or in Kapchorwa town. Fresh beans were traded on a smaller scale at market stands, and only by women. Most interviewed traders got their beans from the farms themselves. Many also alternated, so that occasionally they picked up the beans themselves and other times the farmers brought them straight to their shop. It is not unusual for the beans to travel distances between 3 and 30 km.

Thus, transport is a crucial part of this step. The most common mode of transport is via motorbike. Traders pay local motorbike taxis (*boda bodas*) to carry the crops. Some hire vehicles or go by minivan together with other traders. Only one of the interviewees had his own truck for transportation. Therefore, most people pay for hired transport, which the interviewees stressed as a financial burden. Physical losses often occur at this point due to the same reasons mentioned in the postproduction step, i.e. leaking sacks, bad roads, rain impacting the beans' quality, and accidents. Another challenge that came up in conversations with traders was careless loading and unloading that leads to sacks ripping and beans spilling.

After transporting the beans to the store, some of the interviewed farmers would take a few more steps before storage, especially when the beans were rained on. Some would spread the beans outside again for drying, to prevent rotting during storage. Many would winnow again to clean the beans and increase their quality. For that purpose, they used special winnowing trays resembling large strainers that separate dirt. For fresh beans the traders sourced the beans in the pods and had to pick them out before selling. The losses of dry beans during these processes are particularly minor according to the traders due to their slightly more advanced equipment. During the sorting of the fresh beans, losses depend a lot on their quality: if the beans get wet, many need to be sorted out due to rot and germination.

Another significant part of distribution is storage. Traders usually buy in bulk and store the sacks in their shops for up to one year. The storage techniques are the same as farmers': elevation on wooden pallets and in sacks. Consequently, the previously mentioned challenges of pests are also the same. The difference between traders' and farmers' storage is mostly that many traders have stone shops and do not need to store in their homes. The stone shops offer slightly more protection from pests and moisture. Fresh beans are stored on top of the sacks and spread out on the floor overnight to minimise rotting. However, rotting can still happen. Major reasons for losses mentioned by traders that trade at the market and store fresh and dried beans in the communal wooden storage spots included water leakages and cows breaking in and eating the crops. Traders stated a few other minor sources of losses. One of them is rain during trading, which can lead to reductions in quality due to a lack of rain protection, and spillage when moving the sacks around too much. Another minor source of loss is simply consumers filling up their bags and dropping beans while measuring.

Generally, traders did not seem to be as impacted by losses as farmers. Only two of them said that they felt strongly impacted by the losses, while the other described the impact as rather weak. This can be attributed to the difference in frequency of the losses as compared to the previous stage. Most traders said that losses occur occasionally rather than always, as farmers described. The traders' loss hotspots occur during storage and transport, based on their approximations. Overall, the traders estimated a total **physical loss** during distribution of 18%, which combines with a 3% **quality loss** for a total **economic loss** of 21%. So based on these estimates, the total economic loss of traders is 15% less than that of farmers, which explains the difference in impact of losses on the actors. Like farmers, losses are worse during rainy season. Moreover, during this stage beans do not experience **nutritional losses** because transportation, heavy sun exposure, and storage do not impact the nutritional content of beans, as explained in the section on the postproduction stage.

5.2.2. Nightshade

Compared to bush beans, nightshade is traded on a much smaller scale. As mentioned above, many farmers simply trade with neighbours in a non-commercial setting, however some trade on a bigger scale. During the field observations and LT, it was observed that traders often buy the crop from farmers and walk to the city to sell it to other traders, who then sell it to consumers. Another common practice appeared to be farmers directly selling their entire yield to schools or restaurants. These trading activities mostly took place via walking and occasionally via motorbike. Traders considered hiring a motorbike to be a financial burden, so they preferred walking for many hours, carrying the nightshade on their heads. To that end, the nightshade is usually packed into big white sacks for transport and sold straight away. According to the farmers and traders and based on the field observations, this packaging and transport usually does not lead to physical losses if performed well. Occasionally, the sacks can be packed too tightly, leading to minor losses as the leaves get damaged and quality is reduced. This mostly happens when the sacks are tied too harshly on the back of a motorbike, according to traders.

Before transportation traders sometimes washed the nightshade again, but they did not engage in activities such as sorting or drying as they did with beans. Hence, there are fewer opportunities for traders to experience losses. Minor losses due to dropping during trading were observed during the LT. When sorting the nightshade into bundles and handing them over to the consumers, parts can drop due to careless handling. However, this loss was a nearly negligible 0.3% (see Figure 9). During the trading itself, it was observed that women mostly spread the nightshade out on sacks on the floor or wooden market stands. This usually took place under full sun exposure. Some of the traders reported that usually they do not experience losses but that if the sun is very harsh and demand is low they can lose quite a lot to wilting. Three hours was described as the average time that it takes them to sell out. Nonetheless, during times of high supply it can take the entire day and during times of low supply and high demand it can take one hour or less. Of course, this also depends on the traded quantities. Moreover, nightshade is often passed from trader to trader before finally reaching consumers. Hence, there appears to be an insufficient link between producers and consumers, which causes nightshade to be exposed to sun for longer than necessary. If the women do not sell out, they take the remains home for their own consumption, as the nightshade would rot overnight and would not be vendible next day.

Consequently, the loss hotspots during the distribution of nightshade occur mostly during trading at the market due to heavy sun exposure. Based on the estimations of the traders they experience an average total **physical loss** of 5%, including transport and trading. Thus, the physical loss is not as significant for nightshade as it is for beans. However, the **quality loss** of nightshade is 4% and, therefore, almost equal to the physical loss (total **economic loss** of 9%). Due to welting or signs of pests, traders were forced to sell for lower prices or to sell bigger bundles for a regular price. Hence, the quality loss is almost as severe as the physical one. Still traders did not feel strongly impacted by the losses in general.

The **nutritional loss** during trading is much more significant than the physical loss. The loss of vitamins in nightshade is not visible, which means that it can be sold despite having lost much of its nutritional value. This effect could be considered an invisible quality reduction. The transport takes place in sacks so that the crop is protected from direct light exposure. Nonetheless, the heat exposure during transport varies depending on whether traders walk in the shade or sun. During the LT the nightshade was once transported on a motorbike for around 10 minutes in the early evening, once for two hours via walking with heavy sun exposure, and the last time also for two hours walking with shade and sun. Hence, the nutrient loss during transport varies significantly. The losses during trading are likely to be more severe because the crops are often continuously exposed to heavy sunlight. According to the interviewed food scientist, nightshade could potentially lose all its vitamin C when exposed to sun all day. Consequently, the level of the loss again depends on time and intensity of exposures. Significant reductions in nutrient content can generally be expected.

5.3. Consumption

Consumption is the last stage of the VC and involves local preparation and consumption habits (Schuster & Torero, 2016). Hence, during this stage the focus is less on commercial activities and more on preparation traditions at people's homes. However, this stage includes all losses that the consumer faces from purchase on including transportation and storage at home until preparation and, finally, consumption.

5.3.1. Bush Beans

Some interviews with restaurant owners provided insights into the local consumer culture. Often farmers and traders directly supply the restaurants so that transport does not play an important role. Only occasionally would the interviewees purchase beans themselves at the nearby market and thereby encounter minor transport losses due to leaking plastic bags. For the small-scale consumer purchases of a few kilograms, bush beans are packed and transported in thin plastic bags that are prone to ripping. The other half of the interviewed restaurant owners buy beans in bulk and store them the same way as farmers and traders. Hence, they encounter the same kinds of storage losses. Some, however, would prepare the beans right away and thereby avoid such losses completely. Thus, these kinds of losses are generally less during this stage. Before preparation the beans are always sorted to separate broken or rotten beans. This is the only point during preparation where a physical loss occurs. Based on the restaurant owners' estimates, during the entire process of purchase until consumption 15% is lost **physically.** This includes occasional transport, storage, and sorting losses before consumption. There is no difference in quality because cooked beans are always sold to consumers for the same price, no matter the original quality. During the LT session, the pre-cooking sorting to separate good from bad beans resulted in loss of 8% (see Figure 8).

The preparation process entails a few steps, which all interviewees, including farmers, traders, and restaurant owners, were asked about. Firstly, the beans are sorted. After sorting the beans, only three interviewees would wash and soak the beans. The others would wash and boil them right away. The boiling time depends on whether the beans are fresh or dried. Most of the interviewees cooked fresh beans between 30 minutes and 1 hour. Dried beans were mostly cooked for 2 to 3 hours. However, five locals cooked beans for 4 to 12 hours. After boiling them in water, they are usually then fried for up to 30 minutes in a pan together with additional ingredients such as tomatoes, onions, and spices. During the cooking process a brown sauce is created from the beans, which is normally consumed and not poured away. All interviewees stated that bush beans are crucial for the food security of their households and many consume it every day of the week. Compared to the previous stages, the losses during this stage appear to be the least, quantity-wise; the hotspot occurs during the sorting.

However, during the consumption stage it is most important to look at the **nutritional losses** as crops are exposed to a variety of factors. Firstly, the soaking of beans can impact their nutritional build-up if the water used for soaking is poured away instead of being used for boiling (Pujolà, Farreras, & Casañas, 2007, p. 1040). Iron is a water-soluble nutrient, which means that it diffuses into the water during soaking. The same goes for starch, which is a carbohydrate and source of calories. However, if the water is used for boiling and then consumed, then the iron and starch content remains in the water. Consequently, if the soaking water is poured away, water-soluble nutrients are lost, which is why soaking is not necessarily recommended. The same goes for the water used for the boiling of the beans. However, in Kapchorwa it is a very common practice to use the bean sauce created during boiling, so these nutrients are typically not lost. Besides, covering the beans during boiling so that evaporating water cannot leave the pot prevents water-soluble nutrient loss through water vapour.

As the interviews have shown, locals tend to boil and fry the beans for very long periods of up to 12 hours. Nonetheless, the long boiling times do not cause a nutritional loss. Protein and iron are the most important component of bush beans, and both are heat stable, which means that they do not break down when exposed to excessive heat for long periods of time. Protein changes its structure, but not its content, when exposed to immense heat. The protein and starch content can even increase due to boiling, as it becomes digestible (Pujolà et al., 2007). Consequently, the boiling practices of beans have little to no impact on the nutrient content if the water is consumed. Therefore, the nutritional loss is insignificant. However, compared to the previous VC stages, the consumption stage has the most potential for nutritional losses since nutrients can be poured away along with the used water. Additionally, boiling beans for such long periods of time requires plenty of resources, such as firewood, charcoal, and time, which are wasted from an ecological and economic point of view.

5.3.2. Nightshade

Most interviewees stated that nightshade is an important vegetable for their home's food security, but not as important as bush beans. It is usually consumed between three and seven days per week, in combination with other ingredients or simply on its own. Transportation of the crop to the point of consumption, that being locals' homes or the restaurants, generally does not pose a challenge with nightshade, according to the interviewees. Once purchased, nightshade is prepared within the next hours since it cannot be stored. Only one of the restaurant owners out of all interviewees owned a fridge to store nightshade for longer times. However, since it is typically not stored there is no measurable storage loss. The predominant loss occurs during sorting when the edible leaves are separated from the hard stems. Large parts of the plant are usually not eaten and thrown away. After sorting them out, locals customarily wash the nightshade again and then boil it. There are usually no physical losses after the sorting process. Hence, the total **physical loss** at consumption is 28% based on interviewees estimates. During the LT the total amount of nightshade that could be consumed was measured four times, and the average loss due to sorting was 40% (see Figure 9).

All interviewees were asked about their consumption practices, which were the most significant sources of **nutritional losses** in this case. Before boiling, the nightshade is usually washed one more time, which again does not lead to significant losses of nutrients as explained during postproduction. Most locals stated that they boil nightshade between 30 minutes and 1 hour until it is "very soft". A few even specified that they boil it for up to three hours. After boiling, many still fry it with additional ingredients such as milk or peanut paste to reduce the bitter taste of nightshade. The nutritional impact of these forms of preparation again depends strongly on the time of exposure. Still, some general conclusions can be drawn. Minerals are generally not as heat sensitive as vitamins, so their losses are less. However, calcium, which is one of the more prominent minerals in nightshade, can still be impacted by long boiling times. Moreover, vitamins A and C are heat-sensitive and therefore impacted by boiling. Vitamin C is also water-soluble, so it can get lost via evaporation if not covered, or if the water used for boiling is poured away. Many women reported that they pour out the boiling water up to three times to reduce the bitter taste, which could lead to a highly significant or even complete loss of vitamin C. Previous research found that up to 81% of vitamin C in green leafy vegetables is lost in blanching water (Ajayi, Oderinde, & Osibanjo, 1980, p. 246). Vitamin A is oil-soluble, so it can be lost during frying. Depending on these factors, significant amounts of mostly vitamin C, but also vitamin A, can be lost (Van Jaarsveld et al., 2014, pp. 80-81). Boiling, steaming, and frying differ in their cooking temperatures. Boiling takes place at 100 degrees Celsius, while frying reaches even higher temperatures, and steaming higher still. However, the intensity of the loss depends, amongst other factors, on the duration of exposure and the exposure to water. Boiling might be at the lowest temperature, but it can still lead to the highest losses of water-soluble nutrients.

5.3.3. Waste of Bush Beans and Nightshade

Observations of the consumption practices of bush beans and nightshade revealed that food is usually not wasted at consumer level. Only one of the respondents said that occasionally his family must throw away food due to miscalculations of the required quantity. The rest of the interviewees stated that all cooked food is always consumed by their family, as they cook precise amounts. If they do not consume all food on the day of preparation, it is either reheated the next day, or fed to their dogs or cats. This was the case for both crops and is in line with the findings of FAO (2011) that PHLW in SSA does not commonly occur at consumer level, but during previous VC stages. Two of the interviewed restaurant owners mentioned that consumers tend to leave leftovers when eating out. One of them stated that this is always the case, the other explained that consumers only waste when there is excess supply of the food at the time. Hence, when it is not harvest season people usually finish their plates as the crop is rare. Consequently, there could be a difference between people's home consumption habits and their consumption habits when eating out. However, this difference requires further targeted investigation, which is beyond the scope of this research.

6. Discussion & Interventions

6.1. Physical Losses

Several differences become apparent when comparing physical losses of bush beans and nightshade. The total estimated physical loss of bush beans is up to 59% (see Figure 7). The total estimated physical loss of nightshade is 39-52%, depending on whether field losses to pests are included. This research's findings on nightshade are in-line with the general loss estimations of 50% of fruits and vegetables in SSA by the FAO (2011, p. 7). However, the estimates of losses of pulses in SSA are almost half of what this research has found. One of the explanations for this discrepancy could be that this research was conducted during the rainy season, during which losses are much more dramatic compared to the dry season. Moreover, it could point to losses of beans in Kapchorwa generally being more severe than the SSA average.

At the beginning, it appeared likely that more nightshade gets lost due to its increased perishability as well as the findings by the FAO. However, that has proven not to be the case when taking a closer look at both VCs. One of the explanations for this disparity could be the general difference in VC stages. The VC of nightshade is much shorter than that of bush beans. Nightshade can go through all steps from harvest to consumption within one single day, as distribution occurs in close proximity to production. It does not go through any value-adding activities as it is sold fresh on the day of harvest since it cannot be stored under local conditions. Consequently, there are very few opportunities during handling where physical losses can occur. 54% to 72%[5] of the total loss occurs during the consumption stage, so only a small portion of losses occur throughout the previous stages. The bush bean VC is much longer and offers many more loss opportunities during earlier VC stages. Harvesting alone is much more time-consuming and the beans go through a much longer postproduction process. As opposed to nightshade, which is simply washed and then transported to consumers, bush beans are usually threshed, dried, winnowed, and sorted, and only rarely sold fresh. All these steps can take around one week, and can compound losses. Moreover, bush beans can then be stored for around three months or even up to one year, which offers a large time frame for losses to occur. The consumption stage only makes up 25% of the total losses, as opposed to the potential 72% in nightshade VCs. Therefore, the mere difference in time frames of the VCs of both crops offers different challenges and opportunities. When looking at each VC stage in comparison these discrepancies become apparent.

Based on estimations, nightshade farmers experience 7% less loss during production and postproduction than bush bean farmers (19 vs. 26%; see Figure 7). However, particularly for nightshade the production loss can increase rapidly in case of a large-scale pest infestation on the field. For both crops, farmers stated that the most apparent losses occur on the field before harvest due to rotting, over-drying, or pests. Hence, the production of either crop seems to be rather challenging, due to poor harvest timing and pest controls. However, generally it is evident that the

[5] % depending on the inclusion of losses on field due to pests

interviewed farmers experience around 20% less losses during the postproduction of nightshade. They stated that there are no significant losses during this stage, while bush bean farmers experienced loss hotspots during post-harvest handling, storage, and transport. These hotspots were confirmed by four extension officers during the KIIs. They stated that for both crops, harvesting itself is a major challenge and reaffirmed the aforementioned reasons. They specified that they see post-harvest handling of beans overall as the biggest challenge due to the lack of more advanced techniques and that losses of beans are much more significant than losses of nightshade. Generally, it could be observed that problems during harvest such as rotting would often be moved into the postproduction stage, increasing measured losses there. Nightshade farmers would usually sort out bad plants and leave them on the field, so that they would only negligibly impact the following VC stages. Moreover, many farmers of both crops mentioned that thievery is a problem and that thieves steal entire harvests from their storage or from fields directly. However, since stolen crops are not technically lost, they are not included in the loss approximations and measurements. Overall, the interviewed extension workers agreed that bean farmers are by far most impacted by losses. In cases of largescale nightshade pest infestations, farmers would be extremely impacted. Nonetheless, if this is not the case, they are not very affected.

During distribution, physical losses are less compared to the previous stages, particularly for bush beans. Nonetheless, bush bean traders experience an estimated 13% more losses than nightshade traders (18 vs. 5%; see Figure 7). According to the interviewed traders, the bush bean loss hotspot is during transport and storage, while for nightshade it occurs during market trading. Again, the crops differ immensely in this stage. Bush beans are more difficult to transport as they are too heavy to be carried like nightshade, making losses more likely for beans. Moreover, traders store beans for longer times whereas nightshade is sold the same day, which offers fewer opportunities for losses. The trading itself, though, is more challenging with nightshade, as it is much more sensitive to sun while beans are not impacted by it at all. Contrarily, losses for bush beans occur mostly during the activities before and after trading, namely storage and transport. Overall, the losses are lowest during this stage, so that traders are the VC actors who are least impacted by the loss situation, according to the interviewed traders themselves as well as the extension officers.

In the consumption stage, the loss distribution between the two crops changes entirely. With 28% compared to 15%, consumers lose almost twice as much when preparing nightshade as they do with beans. Large amounts of nightshade need to be sorted out before preparation as they are not eaten, while good quality beans can be eaten in their entirety without sorting. Only few damaged beans are discarded.

Consequently, postproduction and distribution are spread over a much longer period of time for beans than for nightshade, offering many more opportunities for losses. Therefore, the losses for beans greatly exceed those of nightshade during these activities. During consumption the opposite is the case, as nightshade must go through a more intense sorting process before consumption. However, the overall VC losses of bush beans are greater. Consumer waste was minimal for both crops. Based on this it can be concluded that the physical loss hotspot of the bush bean VC is during postproduction, more precisely during storage, transport, and post-harvest handling. For nightshade it is the sorting during the consumption stage. Still, it can shift to the production stage in case of large-scale pest infestations.

6.2. Economic Losses

Economic losses express physical losses in monetary terms. However, they also add monetary losses due to quality reductions of the sold product. Hence, analysing the economic losses allows assessment of the impact of the different VC stages on the quality of bush beans and nightshade, and provides insights into the impact of losses on the economic situation of different VC actors. As previously mentioned, the impact of market forces on economic losses was not examined. Overall, due to the higher total physical loss throughout the bush bean VC, the total financial loss is also higher than that of nightshade (47-60% vs. 72%; see Figure 7). However, the comparative quality reduction, or economic loss compared to the physical loss, can be assessed by looking at the postproduction and distribution stages, throughout which the quality loss was calculated[6]. The magnitude of the quality loss is much higher for nightshade: a 11% physical loss for nightshade results in a 19% economic loss, meaning that 42% of the economic loss is attributable to quality reductions. Bush beans go from a 44% physical loss to 57% financial loss, meaning that only 23% of their economic loss is due to quality reductions.

When quality reduction is calculated for only the postproduction stages of the VC, the same pattern can be observed: On the one hand, bush beans farmers experience 28% of their postproduction financial loss due to quality reductions (26 vs 36%; see Figure 7). On the other hand, nightshade farmers experience 40% of their financial loss due to quality loss (10 vs 6%; see Figure 7). Once again, the higher financial loss is experienced by bush bean farmers, but nightshade farmers' crops experience a greater price reduction due quality reduction. The distribution stage mirrors this pattern yet again, albeit the economic loss of bush bean traders generally decreases rapidly compared to the previous stage while it remains the same for nightshade traders. 44% of the total financial loss of 9% is due to quality reduction for nightshade, compared to only 14% of the total 21% for bush beans (see Figure 7). The financial loss during the consumption stage is the same as the physical loss as all food is consumed regardless of its quality. If the quality is so low that the food is thrown away, then the loss is counted as a physical loss instead of a quality reduction. Overall, the economic and physical losses decrease throughout the VC of bush beans while economic losses remain the same for nightshade.

Quality reductions are not solely related to the perishability of a crop. Consumers usually have precise quality criteria which they look for when buying beans and nightshade. According to the interviewees, bush beans must be free of dirt, they should not be damaged or infested by pests such

[6] Quality loss is the difference between in value between a best and lower quality product and can therefore only be assessed during stages where the product is sold (Ward & Jeffries, 2000, p. 3)

as weevils, they should not be germinating, and the varieties should not be mixed. Nightshade should have big green leaves with no pests or holes, and should be clean and fresh-looking. These quality requirements are closely linked to the post-harvest handling of the crops. Hence, inadequate handling at the beginning of the VC can lead to economic losses throughout the chain. If the nightshade is not harvested in time, then the leaves run higher risk of being infected by pests and becoming lignified. Also, if not cleaned sufficiently, or if packed too tightly, the quality will suffer, increasing economic losses. The same goes for bush beans. Especially when farmers have no equipment (e.g. tarpaulins), beans are dried on the ground and it becomes difficult to separate the varieties from each other and to keep them clean. Bedsides, beans might not be dried properly leading to rotting or germination later during the trading. However, bush bean traders can still increase the quality of the product by cleaning, drying, and re-sorting, and thereby reducing economic losses later in the VC chain. Particularly the goods of the traders without access to the resources for these quality-increasing measures after sourcing will suffer from inadequate post-harvest handling. On the other hand, nightshade traders receive the crop in a certain condition and cannot increase its quality much either way, so economic losses for them cannot be so reduced.

Nightshade consumers experience the highest financial loss out of all VC actors (28%), while the opposite is true for bush bean consumers (15%). The high sorting loss of nightshade, due to inedible parts and bad quality, leads to high economic losses, as consumers pay for much of the parts of the plant that are not eaten. Indeed, two extension officers reported that consumers are the actors second-most impacted by bad-quality goods, only after farmers who experience the worst physical losses. Particularly for nightshade, this assertion was supported by direct observation.

Therefore, financial losses due to quality reductions appear to be a bigger challenge for nightshade than for bush beans, even though the total financial loss is estimated higher for bush beans. Nightshade is highly perishable and sun-sensitive and locals lack means, such as cooling facilities and sun protection, to maintain high quality throughout the VC. Thus, the quality loss hotpot is mostly while marketing during the distribution stage. For beans, quality reductions also take place particularly when the crop encounters pests or moisture. Storage during postproduction, hereby, poses the biggest challenge for bush beans making it the quality loss hotspot. However, if locals dry the beans properly and take basic measures against pests, quality reductions can largely be prevented. Such measures are elaborated on during the following section on interventions.

6.3. Nutritional Losses

Bush beans are estimated to experience much higher physical and economic losses compared to nightshade (see Figure 7). The opposite is the case for nutritional losses. During all stages, bush beans experience relatively insignificant nutritional losses unless the water used for preparation is poured away. On the other hand, nightshade has the potential to experience significant nutrient losses particularly during distribution and consumption.

Protein and iron, as some of the most important nutrients in beans, show little to no sensitivity to local post-harvest handling and consumption practices. Vitamin A and particularly vitamin C in nightshade show much more sensitivity to external factors, such as light, heat, and water. Post-production practices are not likely to cause significant nutrient reductions. However, distribution and especially consumption can lead to significant reductions or even complete losses of vitamins. During the distribution of nightshade, it was observed that farmers commonly pass on the nightshade to traders, who pass it on to one or even two other traders. All of this takes place under heavy sun exposure and without cooling, so that nightshade is exposed to sunlight unnecessarily long and the VC is extended. Many consumers also purchase nightshade straight from the farmers, which is much more efficient from a nutritional point of view.

Nonetheless, the significance of these losses for local malnutrition requires further assessment. The human body cannot absorb 100% of all nutrients either way, so some losses are not likely to impact the actual nutrient uptake. Moreover, certain forms of preparation such as boiling might cause losses of some nutrients, but they can also make them more easily absorbable for the human body, as it is the case for bush bean (Ajayi et al., 1980, p. 246). Therefore, nightshade is likely to experience significant reductions of nutrients throughout the VC, but the actual impact of those losses on human nutrition still has to be assessed. This task is beyond the scope of this research. Still, it can be concluded that the nutritional loss hotpot for both crops is during cooking. For beans, losses are caused mostly by water exposure, and for nightshade, by heat, water, and oil exposure.

6.4. Interventions

Farmers, traders, and consumers face a variety of challenges in Uganda, many leading to significant post-harvest losses. For bush beans, farmers appear to be facing the most losses, and are therefore most impacted. For nightshade, overall losses are less than for bush beans. However, farmers and consumers have shown to be the most impacted. There are a variety of interventions that could improve the local loss situation significantly. During the field study local practices were observed, and local interventions of farmers experiencing less losses were identified. Moreover, by asking people for improvements that they would like to implement, the desired focus of interventions could be determined. According to local extension workers, the uptake of changes in agricultural practices and post-harvest handling is slow, and people are afraid to take risks. Consequently, it is important especially at first to recommend interventions that local farmers and VC actors desire and would be willing to implement.

6.4.1. Local Interventions

Local loss interventions observed during the field visit were mostly small in scale. The most frequently employed measures were precise harvest timing, using of tarpaulins for all post-harvest activities, and better quality, newer sacks. The most prominently used loss reduction technique was spraying, particularly for nightshade. Spraying was performed on the fields to prevent pest infestations for both crops. It was also performed during the storage of beans, as sacks were sprayed from the inside and outside. People often did not have the means to invest in proper storage. Hence, they would regularly employ methods that dealt with the symptoms rather than the source of the problem. Pouring ash over the sacks during storage, instead of pesticides, also came up more frequently when speaking to traders. One extension worker mentioned a local plant that can be dried and added to the bean sacks during storage to prevent pest infestations. VC actors also implemented several techniques to cope with the bad roads, namely the use of two sacks to prevent dropping of beans and transporting one bag at a time on the motorbike. Additionally, the traders that re-cleaned and dried their beans faced less problems during storage due to the decreased moisture content. Some of the restaurant owners and consumers mentioned that they source straight from farmers to get higher quality products. These are some measures that locals are already taking to reduce losses.

When asked what further measures they would like to take, many farmers mentioned better pesticides, particularly for nightshade. However, measures that were slightly wider in scope were also proposed by bush bean farmers. One of them was increased seed variation and certified seeds, to increase yields and decrease losses on the field. This was seconded by an extension officer, who stressed the positive impact of good quality seeds. Another measure farmers would like to take is employing more workers to help with harvest and post-harvest handling to increase the efficiency and timing of these stages. All extension officers interviewed stressed the importance of training in improved drying and harvesting techniques, as the traditional techniques are outdated and inefficient. However, only two out of all the interviewees had ever received training by extension officers. Consequently, an expansion of the training network is much-needed since traditional and potentially flawed techniques are passed down for generations without proper training.

During postproduction and distribution, traders and extension workers mostly stressed storage as the most important factor to improve when dealing with bush beans. Such storage should have air ventilation coming from two sides, air space, and stable elevation from the ground. High-quality sacks are also an important part of such storage facilities. However, one of the local problems is that there usually is not enough supply of the thicker, high-quality sacks, which creates a barrier. For nightshade traders the most important part is sun protection. A tarpaulin can be used for this purpose, but many traders cannot afford them. Moreover, one of the extension workers mentioned that improved market information could make nightshade trading much easier. Instead of simply harvesting and then trading, the harvesting days could be better determined by market demand to avoid surplus, which can lead to increased losses.

Consequently, the interviewed actors showed specific interest in improved pest control and harvesting techniques, as well as storage and market location improvements. Lack of financial resources is the barrier that stops most of them from currently taking these measures.

6.4.2. Innovative Interventions

There is a wide variety of interventions to reduce PHLW which were identified in the literature review section. Since the major barrier stopping actors from taking further loss reduction measures is money, many of those interventions will not be feasible in the local context of Uganda without funding. However, previous research has assessed a variety of PHLW interventions' feasibilities in a smallholder farmer context in SSA (Jones et al., 2015). They were tested on their potential to "secure livelihoods", "revalue ecosystems" and "advance health" (Jones et al., 2015, pp. 13-15). Many of the interventions found suitable in Jones at al.'s research could also be implemented in the context of Uganda.

Firstly, the implementation of an information tool for weather and market forecasting could reduce losses (Shafiee-Jood & Ximing, 2016, p. 8437). Harvest and post-harvest handling depends strongly on weather conditions. Sudden rain during transport or drying can rapidly increase losses during this stage. Hence, adequate forecasting would give farmers the possibility to adjust their harvesting schedules according to local forecasts, especially for bush beans. For nightshade, market forecasts would be more important since the crop is not as impacted by rains. Increased market knowledge can help farmers and traders avoid oversupply, which can reduce losses as nightshade needs to be sold straight after harvest. This intervention would improve both the VC process and the quality of the product. Moreover, this could make postproduction more time-efficient, which was mentioned as a desired change by several interviewees. This means they are likely to be more willing to make use of this innovation.

Secondly, Jones et al. found a variety of improved storage techniques that decrease losses. "Heavy moulded plastic containers" are cost-effective and durable, and can be used for the storage of perishable crops such as nightshade (Jones et al., 2015, p. 10). Particularly during storage at the market and transportation, they can protect nightshade from damage due to harsh tying and direct sun exposure. This plastic containers could reduce losses and protect the nutritional value for which light and temperature management are most important (Jones et al., 2015, p. 17; Lee & Kader, 2000, p. 217). However, since nightshade traders do not experience losses as very impactful and are mostly not aware of the influence of heavy sun exposure, they might not be willing to invest in these containers. Besides, most women carry the nightshade bags on their heads, which might be more difficult with this innovation.

For bush beans, "ZeroFly Bags" would be a strong alternative to the currently-used storage sacks. These bags are insecticide-impregnated to prevent pest infestations for dried crops, such as beans, and thus they reduce losses at storage level. "ZeroFly" bags make the purchase of additional pesticides unnecessary, which makes them a good investment. Further, they reduce toxins at market level, and the locals are familiar with the use of those specific chemicals. Most interviewees stressed that they need more of them to improve post-harvest handling. Hence, the reactions to this innovation would probably be rather positive. Nonetheless, supply of normal bags can already be problematic in Kapchorwa, which means that for such interventions to be a success, overall supply of agricultural equipment needs to be improved.

"Direct Sourcing" has proven to be highly efficient in reducing losses and improving market linkages. It can be defined as a "procurement channel where farmers establish contractual agreements directly with buyers" (Jones et al., 2015, p. 10). This way especially storage losses can be reduced. Moreover, it creates more market stability and higher incomes and is applicable to a wide variety of crops, including both nightshade and bush beans. Contracts remove supply and demand fluctuations and enable more precise marketing. The analysis has shown that, especially for nightshade, quality continuously decreases throughout the VC and nutrients are lost. Moreover, nightshade is often passed between several traders before reaching consumers, which extends the VC and compounds quality reductions. For bush beans, inefficient marketing is not as much of a problem, but storage losses occur in each VC stage. Hence, an intervention that would decrease such losses and create a more precise linkage between VC actors has great potential to positively influence the local loss situation. Some consumers mentioned during the interviews that they source directly from farmers for better quality, so such a system could be expanded in Kapchorwa.

A similar intervention, also targeting the overall functioning of the local VC, is the set-up of "Collection Centres" as "aggregation points that link farmers to buyers, primarily offering grading, packing and storage services" (Jones et al., 2015, p. 10). Such centres offer a centralised place for trade also in larger quantities while reducing PHLW. Mostly, high standards for packaging and storage services can help farmers in overcoming many of their challenges. Besides, this intervention is applicable to all kinds of crops.

"Heavy moulded plastic containers" and "ZeroFly Bags" can lead to major product improvements and loss reductions, and weather and market forecasting, "Direct Sourcing" and "Collection Centres" offer opportunities for process upgrading and loss reductions. Both product and process interventions cut across VC stages and can ideally be combined. All of these interventions were some of the most feasible interventions in the SSA context according to Jones et al., and are in line with the findings of this research. Of course that does not imply that these are the only suitable options for the local context. Still, it offers a starting point for possible interventions, especially in terms of combining product and process interventions. Moreover, sensitisation of local farmers, traders, and consumers is needed to create awareness of loss hotspots and potential improvements. Most importantly, awareness of the impact of different factors on the nutritional value of, particularly nightshade, needs to be spread. Part of this should be the introduction of alternative forms of food preparation to reduce nutrient losses.

7. Conclusion and Reflection

The inherent differences in the VCs of bush beans and nightshade cause the severity and VC stage of their physical, economic and nutritional loss hotspots to vary greatly. The VC of bush beans is spread out over a longer period of time, resulting in severe physical and economic losses. The nightshade VC is usually only one or two days long, and therefore offers fewer opportunities for such losses.

However, while the total economic losses of bush beans are greater, nightshade is more sensitive to nutritional losses and experiences a greater magnitude of quality reduction. Moreover, post-harvest physical and quality losses decrease throughout the bush bean VC, whereas they reach their maximum during the consumption stage for nightshade.

The **physical loss hotspot** of the nightshade VC is during the consumption stage, more precisely during the sorting before cooking, as large parts of the plant are not eaten. The VC actors most affected by this are therefore consumers. Nonetheless, the hotspot can shift to the production stage if the nightshade suffers from a large-scale pest infestation. This can lead to entire harvests being lost and is mostly caused by inadequate spraying. Farmers are most influenced by this as they lose their harvest, and thereby experience major financial losses as well as losing a source of food. The **quality loss hotspot** is most often at the market during the distribution stage. Reasons for quality reductions are mostly heavy sun exposure causing increased welting and vitamin reductions. There is a general lack of sun protection during trading, which is intensified as nightshade is often passed between several traders before reaching consumers. Hence, the VC is unnecessarily extended due to missing links between farmers and consumers, at the expense of quality. Traders can be financially affected by this loss hotspot as the value of their product decreases. However, even more impacted are consumers, who receive bad quality products with extremely low nutrient contents. Still, nutritional losses are even higher during the consumption stage, making this the **nutritional loss hotspot** of the nightshade VC. Losses are caused by extensive boiling times and repeated pouring away of water used for preparation. Consequently, consumers are most affected as they are left with very few nutrients. Overall, the **economic loss hotpot**, therefore, is during consumption, and consumers are generally the most affected nightshade VC actors.

Studying the bush bean VC has revealed its **physical loss hotspot** to be in the postproduction stage. Post-harvest handling, such as drying, threshing, sorting, storage, and transport have all shown to be loss hotspots to a similar extent. During handling and storage the loss hotspot is most stable, while losses during transport can be more severe but are not as frequent. Overall, all three activities are challenging to farmers, who are most impacted by this hotspot. Identified reasons are the lack of adequate post-harvest handling equipment as well as inadequate storage, packaging, and transport techniques. Bad harvest timing was identified as a procedural problem that negatively impacts all following activities. The **quality loss hotspot** is similar to the physical ones but has proven to be most severe during the storage of the beans. Rats, weevils, termites, and potentially rot-causing moisture lead to major quality reductions and sometimes even to physical losses. Such damage decreases the value of the product, leading to financial losses. The actors most impacted by these losses are farmers, who often lack sufficient storage facilities. As opposed to the previously mentioned, more severe loss hotspot, the **nutritional loss hotspot** is much less severe in the bush bean VC. Similarly to nightshade, it takes place during the consumption stage, when the beans are cooked. The potential for nutrient losses is much lower, still, losses can occur if water is poured away, which could impact consumers' nutrient uptake. However, the overall **economic hotspot** is experienced by farmers during the postproduction stage. The combination of physical losses during storage, handling, and transport, as well as quality reductions, comprise the overall VC hotspot. Traders were the VC actors least impacted by losses of both crops.

Based on this analysis, first recommendations for possible interventions were made. Since the underlying reasons for losses of both crops have roots in the VC process as well as the physical properties of the crops themselves, a combination of product and process interventions is advised. However, the local needs and barriers must be considered when implementing such interventions. There is a general lack of appropriate training of all VC actors, particularly amongst farmers and consumers. Consequently, knowledge on better production and postproduction techniques as well as preparation methods needs to be spread. Moreover, many farmers are under immense financial pressures, which makes money a major barrier in implementing interventions in the local context. Financial pressure also makes people less willing to take risks, so those who introduce interventions must do so with empathy.

Overall, all research questions could be answered sufficiently. This research generated first insights into the reasons for and extents of losses in the context of Uganda. A variety of hotspots and impacted actors were identified, and these will guide more targeted support and serve as a stepping stone for the larger EaTSANE project. The methodological framework of IFLAM and LT was applied to Kapchorwa, and the combination of secondary and various primary data types enabled a holistic research approach. The large number of interviews in combination with participation in and observation of different VC activities made possible a detailed understanding of the local loss situation and common challenges.

The generated data is qualitative and measurements are based mostly on approximations rather than precise quantification. Nonetheless, this approach of combining IFLAM with LT offers a strong starting point for a more quantitative analysis of local loss situations. More exact measurements can be targeted towards the identified loss hotspots now that there is a general understanding of the VC dynamics of bush beans and nightshade. Further research could focus on the exact quantification of losses by using a quantitative LT or QLAM approach. Particularly for the bush bean VC, LT was only employed to individual activities rather than the entire VC due to time limitations and delayed harvest. Accordingly, a LT analysis of the entire VC over a longer period of time would be a strong addition to this research.

This study's results on nutritional losses are rather basic: only general estimations on potential losses were made. Indeed, proper measurements of the levels of nutrient losses could not be generated, as more specialised research is needed to study precise nutrient contents and losses, which is beyond the scope of this research. Therefore, future research could focus on proper quantification of nutrient losses in bush beans and nightshade from a food science perspective. This way the proper levels of losses could be assessed. Moreover, the relevance of these losses from a nutrition perspective requires further assessment. The simple fact that nutrients are lost does not mean that there is any impact on human malnutrition. Thus, further research is needed to study the potential impact of post-harvest handling on malnutrition levels in Uganda and to assess the potential improvement of the nutritional value of local diets.

Additionally, the focus of this research lies specifically on post-harvest losses, which does not include the production stage. Nonetheless, harvest activities were touched upon as they were often influential for subsequent losses. Still, an in-depth assessment of the entire production stage would aid in identifying what kinds of pre-harvest interventions could decrease post-harvest losses in the long run. Particularly for bush beans, improvement of pre-harvest and harvest activities is closely connected to an improvement of the post-harvest loss situation.

Overall, weather conditions strongly influenced losses and hence played an important role for most VC actors. Therefore, the seasonal time frame of this research needs to be taken into account when interpreting its results. This research was conducted during the rainy season, which was reported to cause more severe losses than the dry season. The latter has its own potential challenges and corresponding interventions. A comparative analysis between the local loss situation during dry and wet seasons would give insights into the local impacts of extreme weather conditions on losses, particularly from a foresight perspective in times of climate change. Similarly, a more extensive study of the local market dynamics over an entire market cycle would give insights into market forces influencing economic losses. This goes beyond the scope and limited time frame of this research. Nonetheless, many interviewees mentioned the strong impact of shifts in demand and supply on their loss situation, so these could be focal points to gain better understanding of the changing market dynamics. Despite its largely time- and scale-related shortcomings, this research offers primary insights into the local context of Uganda, and holds plenty of potential for further investigations.

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Appendix

Checklist for field observations

Location			
Different variations			
Loss reduction measures			
Measurements/ unit			
Food thrown away			
Prices			
Sanitary conditions			
Animals around processing			
Personal hygiene			
Sun/ rain protection			
Isolation from contaminators			
Cooling			
Storage			
Placement on mat, floor, tarpaulin			
Condition of boxes			
Careful treatment			
Water for cleaning			
Processing			
Drying (ground, mat)			
Flies			
Consumption techniques			

Sensory Score sheet

Location

Damage to crop (insect infestation)	
discoloration	
Presence of mold	
smell	
Breakage/ physical damage	
Sun exposure	

Interview Questions: Groups

Quantity Loss:

1) What crops are being farmed?
2) What are the farming methods and prevailing equipment?
3) How big is your field?
   a) How much of crop X do you harvest per field?
4) How many people are engaged in drying, in trade, in harvest?
5) Where do farmers sell their products and how do they travel there?
6) How long does it take to travel to the market, or how far is the market?
7) How often does one send the product to the market?
8) How do you harvest crop X?
   a) Are there any losses? How much?
   b) Why are there losses?
   c) How do you reduce losses?
9) How do you transport crop X?
   a) Are there any losses? How much?
   b) Why are there losses?
   c) How do you reduce losses?
10) How do you clean crop X?
    a) Are there any losses? How much?
    b) Why are there losses?
    c) How do you reduce losses?
11) How do you sort crop X?
    a) Are there any losses? How much?
    b) Why are there losses?
    c) How do you reduce losses?
12) How do you process (dry) crop X?
    a) Are there any losses? How much?
    b) Why are there losses?
    c) How do you reduce losses?
13) How do you package crop X? (bag/ sac)
    a) Are there any losses? How much?
    b) Why are there losses?
    c) How do you reduce losses?
14) How do you store crop X and for how long?
    a) Are there any losses? How much?

b) Why are there losses?
c) How do you reduce losses?

15) How do you prepare the food? For how long do you cook the food?
a) Are there any losses? How much?
b) Do losses usually occur before or after cooking?
c) Why are there losses?
d) How do you reduce losses?

16) When (time/season) do high losses occur?
17) What is the impact of the loss?
18) What is the trend regarding PHFLs (variation over years)?

Financial Loss:

19) Does quality impact the price?
a) What is the price for good quality per unit? How many units do you sell?
b) What is the price for bad quality per unit? How many units do you sell?

Impact:

20) What is the perception within the community, do they mind the losses?
21) What coping strategies are used to control PHFLs?
22) What do you think is the potential solution to the problem?
23) Is this crop important for the food security of your household?
24) Do you have access to any support services or extension officers?

Interview Questions: Farmers

1) Tell us about yourselves (age, number, experience, ethnicity)
2) Which crops do you farm?
3) What other livelihood activities are you and your household engaged in?
4) Why do you farm this crop?
5) What crop variations do you farm?
6) What is a good quality crop?
7) How big is your field?
   a) How much of crop X do you harvest per field?
8) How often do you harvest the crop per year?
9) How long does it take to harvest the crop?
10) How long does it take to move the food from the field to storage?

Quantity loss:

11) How do you harvest crop X?
    a) Are there any losses? How much?
    b) Why are there losses?
    c) How do you reduce losses?
12) How do you transport crop X?
    a) Are there any losses? How much?
    b) Why are there losses?
    c) How do you reduce losses?
13) How do you clean crop X?
    a) Are there any losses? How much?
    b) Why are there losses?
    c) How do you reduce losses?
14) How do you sort crop X?
    a) Are there any losses? How much?
    b) Why are there losses?
    c) How do you reduce losses?
15) How do you process (dry) crop X?
    a) Are there any losses? How much?
    b) Why are there losses?
    c) How do you reduce losses?
16) How do you package crop X? (bag/ sac)
    a) Are there any losses? How much?
    b) Why are there losses?

c) How do you reduce losses?

17) How do you store crop X and for how long?
    a) Are there any losses? How much?
    b) Why are there losses?
    c) How do you reduce losses?
18) At what point during handling do you experience most losses?
19) How often do you experience losses?
20) Have the losses changed over time?
21) Are the losses seasonal or all year around?
22) Who has tried to help you or others reduce losses? Explain what, when, where, how and the impact of help.
23) Are there any measures that you would like to take to prevent these losses?
    a) What hinders you from taking these measures?

Financial Loss:

24) Does quality impact the price?
    a) What is the price for good quality per unit? How many units do you sell?
    b) What is the price for bad quality per unit? How many units do you sell?
25) There is anytime you cannot sell your food entirely, give the reason?
26) What do you do with the unsold food? Do you ever have to throw it away?

Impact:

27) How do losses impact your business?
28) What is the proportion of food you keep for home consumption?
29) Is this crop important for the food security of your household?
30) Do you have access to any support services or extension officers?

Consumption:

31) How do you prepare the food? For how long do you cook the food?
    a) Are there any losses? How much?
    b) Do losses usually occur before or after cooking?
    c) Why are there losses?
    d) How do you reduce losses?

Interview Questions: Traders

Quantity loss:

1) Tell us about yourselves (age, number, experience, ethnicity)
2) What crops do you trade?
3) Where do you obtain your crops and what time a day?
4) What are the quality standards for this crop?
5) What is the average weight/quantity of your purchase?
6) Do you sell the entire purchase or do you keep parts for home consumption? How much?
7) Where do you sell crop X after buying from farmer, how far is it?
8) How do you transport crop X from buying to selling location?
9) Are there any losses during transport? How much?
   a) Why are there losses?
   b) How do you reduce losses?
10) How often do you go to the market to sell?
11) Do you sell the crop dried or fresh?
12) How do you store or preserve the crop during transport and trading?
13) Are there any losses during trading/selling? How much?
    a) Why are there losses?
    b) How do you reduce losses?
14) How often do you experience losses?
15) Have the losses changed over time?
16) Are the losses seasonal or all year around?
17) Who has tried to help you or others reduce losses? Explain what, when, where, how and the impact of help.
18) Are there any measures that you would like to take to prevent these losses?
    a) What hinders you from taking these measures?

Financial Loss:

19) How much do you pay for cop x when getting it from farmer? (buying price)
20) Does quality impact the price?
    a) What is the price for good quality per unit? How many units do you sell?
    b) What is the price for bad quality per unit? How many units do you sell?
21) How long does it take to sell out the load?
22) How much of the food remains unsold?
    a) Do you ever have to throw away unsold food? How much?

Impact:

23) How do losses impact your business?
24) Is this crop important for the food security of your household?
25) Do you have access to any support services or extension officers?

Consumption:

26) How do you prepare the food? For how long do you cook the food?
    a) Are there any losses? How much?
    b) Do losses usually occur before or after cooking?
    c) Why are there losses?
    d) How do you reduce losses?

Interview Questions: Consumer/ Restaurant

Quantity loss:

1) Tell us about yourselves (age, number, experience, ethnicity).
2) What crops do you purchase?
3) Where do you purchase your crops and what time a day?
4) How do you travel there/transport the crops?
5) How long does it take to reach your home?
6) Do you experience any losses during transport? How much?
   a) Why are there losses?
   b) How do you reduce losses?
7) Is crop X available all year?
8) What is a good quality crop?
9) Does quality impact the price?
   a) What is the price for good quality per unit? How many units do you buy?
   b) What is the price for bad quality per unit? How many units do you buy?
10) What is the average weight/quantity you purchase?
11) How do you store the food at home before and after cooking? For how long?
    a) Are there any losses? How much?
    b) Why are there losses?
    c) How do you reduce losses?
12) How do you prepare the food? For how long?
    a) Are there any losses? How much?
    b) Do you usually throw food away before or after cooking?
    c) Why are there losses?
    d) How do you reduce losses?
13) How often do you generally experience losses?
14) Have the losses changed over time?
15) Are the losses seasonal or all year around?
16) Who has tried to help you or others reduce losses? Explain what, when, where, how and the impact of help.
17) Are there any measures that you would like to take to prevent these losses?
    a) What hinders you from taking these measures?

Financial loss:

18) Does quality impact the selling price?
    a) What is the price for good quality per unit? How many units do you sell?

b) What is the price for bad quality per unit? How many units do you sell?

19) Where do you sell the bulk of your processed product?

20) If there is anytime you cannot sell your food entirely, give the reason and amount?

a) What do you do with the unsold food? Do you ever have to throw it away?

Impact:

21) How do losses impact your business?

22) What is the proportion of food you keep for home consumption?

23) Is this crop important for the food security of your household?

24) Do you have access to any support services or extension officers?

Interview Questions: KII

1. What are the main hotspots of PHLW that you know about? (only for experts, need to specify for other actors)
2. Do you have any data on this?
3. What are reasons for such losses?
4. What is the impact of these losses on society?
5. Do you know on any actions that were taken to counteract losses?
6. Why were they (not) a success?
7. What has been your experience regarding the local uptake of such reduction interventions?
8. Do you have any new ideas for loss reduction measures?
9. Are there any food safety risks involved in the consumption of nightshade/ field peas?
10. How does processing of nightshade/ field peas impact the nutritional value of these crops (e.g. drying, boiling, steaming)?

Interview Findings on Preparation Techniques

Table 4 Preparation Bush Beans

Boiling time	***Number of respondents***
Fresh beans	
30 minutes	4
1 hour	4
2 hours	1
Dry beans	
30 minutes	1
2 hours	2
2-3 hours	2
4 hours	1
6-8 hours	1
All day	1
Fresh/dry not specified	
20-30 minutes	2
1 hour	6
2 hours	5
2-3 hours	3
3 hours	2
3-4 hours	1
12 hours	1
Frying time	
Unspecified	6
3-5 minutes	2
5-10	1
15 minutes	1
30 minutes	3
Soaking	3 (20 minutes/ overnight)

Table 5 Preparation Nighthade

Boiling time	***Number of respondents***
5 minutes	1
20 minutes	2
30 minutes	8
30 minutes -1 hour	1
1 hours	4
1-1,5 hours	1
2 hours	1
2-3 hours	1
Additional frying	7
Solely frying	1