Adaptation of post-harvest loss interventions

'A case study in the Gulu and Oyam district, Northern Uganda'

M.Sc. Thesis by Richard Klink

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Agricultural Economics and Rural Policy Group

Image front page: Pictures of different kind of intervention strategies that are focused on reducing post-harvest losses in the Gulu and Oyam district. From left to right: The centralized Gulu storage warehouse, on farm grain storage warehouses and canopies for farmers markets (photo: author).

Adaptation of post-harvest loss interventions

'A case study in the Gulu and Oyam district, Northern Uganda'

Master thesis Agricultural Economics and Rural Policy submitted in partial fulfilment of the degree of Master of Science in Management Economics and Consumer Studies at Wageningen University, the Netherlands

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Abstract

This research focuses on the adaptation of post-harvest loss interventions in the Gulu and Oyam districts, situated North in the Republic of Uganda, in Sub-Saharan Africa. The problem with previously attempted interventions of various organizations to reduce post-harvest losses in developing countries are identified, and the possible main factors that contribute to this are highlighted. A conceptual post-harvest processing center (PoHaS) framework conceived by the Dutch research institute TNO, is used as a basis to develop further within this research. The main research question was therefore: “Can the PoHaS framework be adapted to increase its chance of being successfully adopted in the research area? This research adopted multiple methodologies, such as a Value Chain Analysis, Inclusive Innovation Framework, Best Practices approach and a Technical Innovation System to gain a holistic perspective on the possible adaptation of PoHaS to the chosen research area. The results obtained through applying the various methods led to valuable insights into how the PoHaS framework can be further developed. How the potential problems in the system can be eliminated or reduced was identified, as well as the means to enhancing the potential economic opportunities in the study area. It was therefore possible to develop a new framework, based on the original PoHaS system. This new framework should have a higher chance of being adopted in the case study areas, and could also possibly be expanded into other areas of Sub-Saharan Africa.

Key words: *Post-harvest losses, Adaptation, Interventions, Value chain analysis, Uganda.*

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Ch. 1 Introduction

1.1 The research problem

Significant amounts of food produced in developing countries is lost post-harvest, with an estimated range from between 15 to as high as 50 percent of the total food produced, thereby significantly reducing food security (FAO, 2013). Among this wastage one can find fruits and vegetables, together with roots and tubers. These crops have the highest wastage rates of all kinds of food (Prusky, 2011). Food losses, which occur during the harvest, post-harvest and processing phases, are the most significant in less developed countries (LDCs), due to poor infrastructure, poor climate control, basic levels of technology and little investment in food distribution systems (Dunn, 2005; Gustavsson, 2011).

When a certain percentage of a harvest is lost, it only contributes in part to the actual crop loss problem; also wasted are all the factors involved in producing that crop (Kader, 2009). Minimizing postharvest losses (PHLs) of already produced food is therefore a more sustainable method of reducing crop losses than increasing production to compensate for these losses (Kader, 2004). Reduction of these losses, especially if it could be achieved economically, would have an “immediate and significant” impact on a local level, especially when staple crops are involved (Prusky, 2011).

In LDCs, the main cause of PHLs is through biological spoilage. Agricultural products lose their value very quickly without proper refrigeration or drying. Also, poor postharvest handling (PHH) of the product can lead to a reduction in both weight and quality losses (Hodges et all, 2011). In order to minimize these losses it is important to understand 1) the biological and environmental factors involved in postharvest deterioration, and 2) the appropriate postharvest technology procedures that slow down food deterioration and maintain a level of quality and safety for the commodities (Kader, 2004).

Although biological and environmental factors which contribute to postharvest losses are well understood (FAO, 2013; Kitinoja, 2010; Rolle & Mazaud, 2002) and although many technologies have been developed to reduce these losses, they have eventually not been implemented due to one or more of the following socioeconomic factors: inadequate marketing systems; poor transportation facilities; poor government legislation and regulation; unavailability of the required tools and equipment; lack of information; poor maintenance (Kader, 2004). Many collective processing schemes have also proven not to be resilient enough to cope with tensions between local cultures, changes in donor support or the lack of trust within the organisational groups (Mansfield, 2005).

The problem is that earlier solutions have not been designed with these factors as main consideration points. To achieve a sustainable positive impact in reducing PHLs in LDCs, the socio-economic factors should be the basis for any development strategy. Overcoming limitations in these factors would greatly increase success rates.

Moreover, the extent to which solutions are adopted for the necessary harvesting and PHH procedures and application of technologies, varies greatly amongst and even within countries (Prusky, 2011). For a sustainable approach to PHL reduction, a specific approach has to be adopted within the context of the relevant value chain, which is dependent on the scale of operation, the intended market and the returns on investment in which each form of technology is implemented (Hodges et al., 2011). The adoption of methods and technologies depend greatly on whether value chain actors can see a clear, direct or indirect, (financial) advantage (Hodges et al., 2011). Many development agencies therefore take a multi-sectorial and value chain approach when recommending strategies that affect scale-appropriate improved practices for reducing PHLs (Larsen, 2009).

While current literature on PHL interventions mainly focus on examples of mono-crop solutions (Kader, 2009; Kitinoja, 2010), this research will focus on a multi-crop perspective. This contributes to the understanding of the variety and number of value chains required to achieve a successfully balanced food economy and grants the opportunity to develop upon this scheme. Underlying the pros and cons of these existing systems, and what can potentially be gained when successful, valuable insights are gained when combining mono-crop systems into multi-crop systems. Focusing on a multi-crop system may also help to overcome the problem observed by Gustavsson et al. (2011) in the processing sector, namely that the seasonal nature of crop production will lead to under-investment in processing facilities because facilities cannot be used all year-round.

1.2 Research approach

The main objective of this research is to develop a conceptual framework for a PHL intervention scheme. This will be built upon an existing scheme known as Post-Harvest Service Centre (hereafter: PoHaS), with the aim of increasing its chance of successful adaptation in the case study areas. The case studies aim to validate this newly developed framework as a sustainable scheme that will lead to an increase in food availability, and local incomes. PoHaS is a scheme conceived by the Dutch research institute TNO. In this research, PoHaS will be adapted into a new framework to increase its chances of success when developing a multi-crop food system with lower PHLs. TNO has accumulated knowledge on developing preservation techniques for perishable goods in PoHaS, as well as creating ICT solutions and business model development plans. A specific feature of PoHaS is the multi-purpose objective for processing staple crops all year round in a single processing centre.

The research question of this thesis is: *'How can the PoHaS framework, which aims to reduce post-harvest losses, be developed further to increase adoption of the system in the case study areas, including multiple value chains and production processing lines, and by utilizing the adoption and implementation of technological innovations that are in context to the area applied?'*

Specific sub-questions are:

- What are the lessons learned from previously attempted PHL interventions, in particular from the implementation and up-scaling of technological innovations in Sub Saharan Africa?
- What possible factors determine the adoption of PoHaS?
- How should the PoHaS be organized, from a value chain perspective?
- What are the main factors that influence technical innovation in the case study area?
- What specific recommendations can be made for adaptation of the PoHaS framework in the context of the case study areas?

The approach to this research study has been developed in four stages as shown in Figure 1. The thesis structure follows the stages of this approach. Although the nature of the analysis is mainly qualitative, a mixed method approach will be used to provide a more in depth understanding of the research problem. The data will be analysed according to a convergent parallel design, where both kinds of data will be collected in the same field assessment.

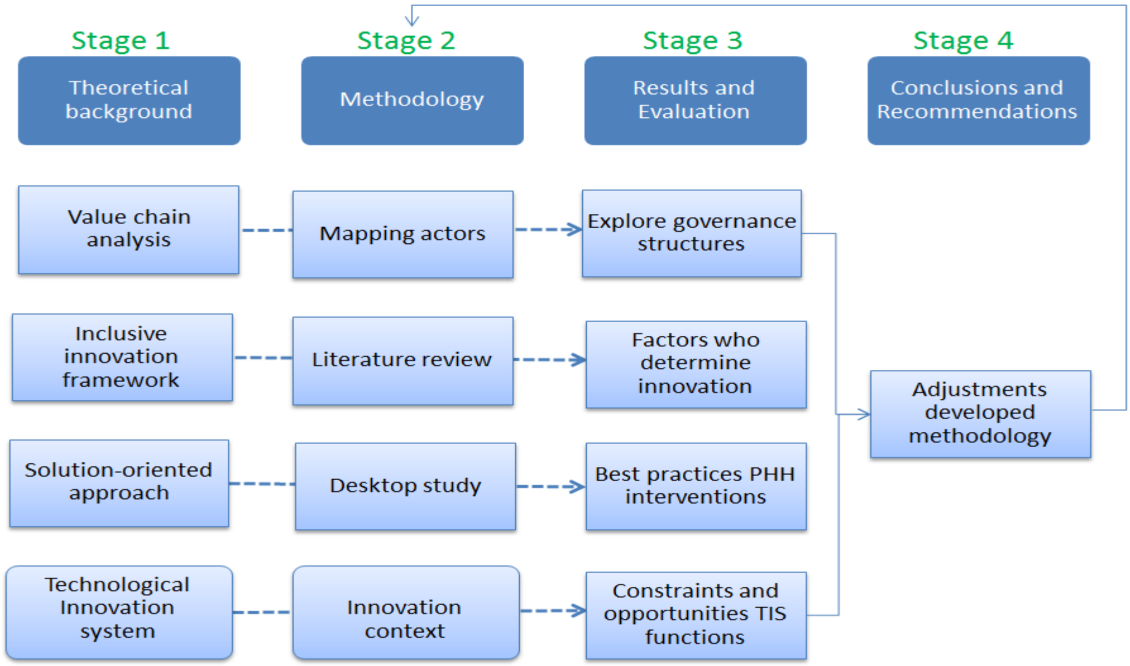


Figure 1: Research approach

1.3 Research area

This study focuses on the Gulu and Oyam districts, situated in the North of the Republic of Uganda (see Figure 2). The main reason for selecting these regions for this study, is due to the high probability of intimate involvement of partner organizations of TNO, in the prescribed regions. Because the concept of PoHaS mainly aims to identify the adoptability of their developed intervention strategy, the location of the study area should adhere to certain parameters. These include factors such as relative safety (the relative stability concerning warfare), levels of agricultural economic activity, supply and demand within the food market sector, accessibility and transport infrastructure (max. 4 hour drive from Kampala), scope of and population within the area[1] and the organisational levels of farmers and processors. These factors insure a level of consistency that is reflected throughout different areas. Therefore the chosen area then gives an indication of situations elsewhere where similar conditions are found. The developed framework for reducing PHLs could then be realistically applied elsewhere in the region. The remainder of this section provides some descriptive statistics about the case study areas.

[1] TNO aims to reach at least 100.000 farmers with the concept of PoHaS

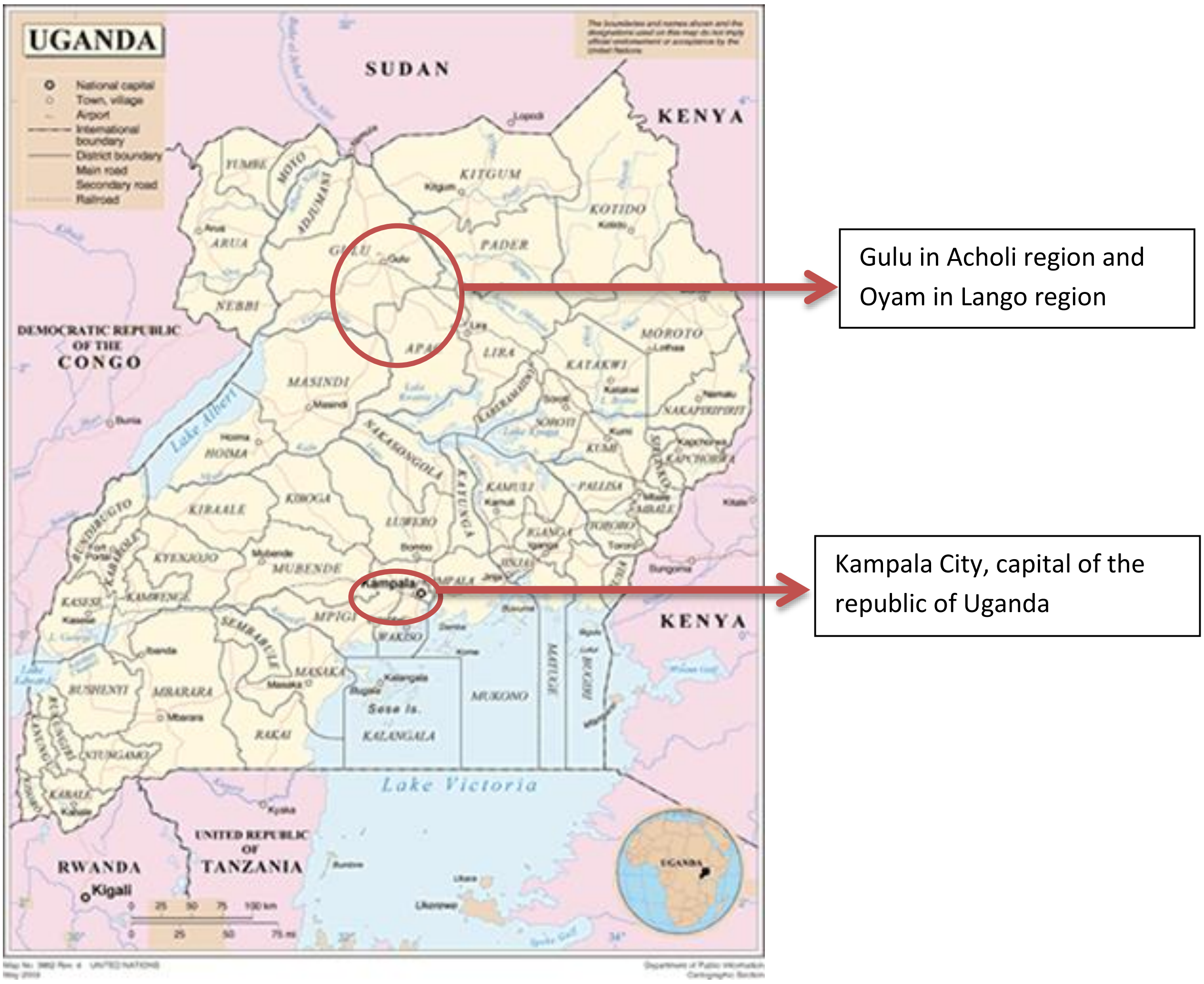


Figure 2: Map of Uganda showing where Gulu, Oyam and Kampala are located

Population statistics

The Uganda Bureau of Statistics estimated the population of the Gulu district to be 396,500 in 2012. The city of Gulu is the commercial and administrative center of the Gulu District and the economic capital of Northern Uganda. The distance between Gulu and Kampala, Uganda's capital, is approximately 320 km by road. Oyam District was established by the Ugandan Parliament in 2006 and borders the Gulu District to the north. The Uganda Bureau of Statistics estimated in 2012, that the population was approximately 378,900 in this district.

Stability of region

There are a wide range of ethnicities, each with their own spoken language in both districts including Luo, Swahili, English and Luganda. This has in the past led to many conflicts in the region and it has undergone periods of instability in the past, related to conflicts. Since the spring of 2007, there has been relative peace in the area due to international pressure calling for the Ugandan government to stop the war and to attempt to reach a peace agreement with the Lord's Resistance Army (LRA). Over 90% of the region's population have returned to their villages after more than two decades of being forced to live in refugee camps, after being displaced from their homes[2].

[2] World Bank. 2013. *Uganda - Diagnostic Trade Integration Study (DTIS) update: prepared for the enhanced integrated framework*. Washington DC; World Bank.

Geographic context and land use

The Gulu district has two growing seasons, primarily an agricultural landscape which is rain-fed, receiving 1300-1400 mm of rainfall between March to May and from July to November. These periods are known being the rainy seasons. Households in this zone primarily consume staple crops, including sorghum and millet, pigeon peas and cassava. Crops such as rice, groundnuts, and simsim are mainly sold as cash crops. The Oyam district is also a bimodal area. This agro-pastoral zone receives between 1210-1330 mm of rainfall annually between the months of March and May and between July and November. The soil found in this zone is relatively fertile, allowing the rain-fed crop production of beans, millet, and cassava, to grow which are generally consumed as food crops. Beans also feature as a main cash crop within this zone, as do groundnuts and maize.

Agricultural economy and the supply and demand of food resources

Most of the households in both zones acquire their food either by producing crops themselves or partly through purchases. Better-off households supplement these food sources with products obtained from their livestock, primarily produce from chickens and small ruminants (goats) as well as from pigs and cattle. Poorer households generally source their additional food needs through means of labour paid for in kind.

Transport infrastructure and accessibility of markets

Market access in both zones is fair to good, with a good feeder road network. However most roads are only accessible certain times of the year and become difficult to traverse along during the monsoon seasons.

Hazards and their consequences

Hazards that have an effect on food availability and accessibility for forms of transportation in this zone include, those created by the weather such as hailstorms and prolonged dry spells, but also through livestock diseases, such as foot and mouth disease. To respond to these hazards, poorer households increase the collection and sale of natural resources. They also augment the amount of work offered through manual labour, and also may begin to rely more on borrowing and/or receiving gifts from relatives. In contrast, better off households in this zone mainly respond to hazards that compromise food availability by increasing their purchases, and, if necessary, selling off livestock to obtain additional cash to buy other food products (Browne, 2010).

Ch. 2 Background Theory

In this chapter the theoretical concepts to be used in this research, are introduced, described and applied to the PoHaS system. The motivation behind the specific choice of theories for the research is to portray a broad overview of the relevant fields involved, to gain a holistic perspective on the possible adoption of PoHaS in the chosen research area. The theoretical frameworks that are discussed include: Value Chain Analysis (VCA); Inclusive Innovation Framework; Solution-Oriented Approach; Technological Innovation system (TIS).

2.1 Introduction and principles of PoHaS

As highlighted earlier, in SSA most of the food losses occur before the products reach the consumer, especially during the stages of PHH and storage, processing and distribution. Therefore, TNO has developed the multidisciplinary concept of Post-Harvest Service Centers (PoHaS), so that markets, through organizing these three steps of the value chain can decrease the food losses. PoHaS consists mainly of two parts; Processing Center and an ICT infrastructure.

The central services for the different post-harvest processes are formed of versatile processing equipment that can handle various crops and produce shelf stable food products all year round (See annex 1 for an overview of versatile processing possibilities). Processes such as drying, cooking, sterilizing, packaging, storage preparation and cooling of fresh products or adding these products as ingredients to non-perishable products such as; cookies, bread, dry mixes, etc. are just some examples. The selection of crops, processing and preparation of non-perishable products depend strongly on the local context. Flexibility with respect to energy sources such as solar power, biogas or other fuels is another aspect to consider. Here, the possibilities for using waste materials to generate energy can be investigated so that the farmers can get benefits from their waste as well.

The business model of PoHas creates value for all the stakeholders involved; farmers, transporters and buyers (Table 1). The business model can create revenues by providing the service of processing to the farmers or by selling the processed products to buyers.

Table 1: The business model of PoHaS

Farmers	Transporters	Buyers
• Low cost, high quality product • Aggregated transport • Quality control • Access to larger buyers	• Aggregated transport • PoHaS always pays • Always full truckload	• High quality product • Information on the availability of the products

PoHaS includes an ICT infrastructure which connects the various stakeholders such as farmers, transporters and buyers to each other. This infrastructure enables them to share information with each other about available products, transport options, market demands and prices so that the trade and transport logistics can be improved. Figure 3 provides a schematic overview of PoHaS.

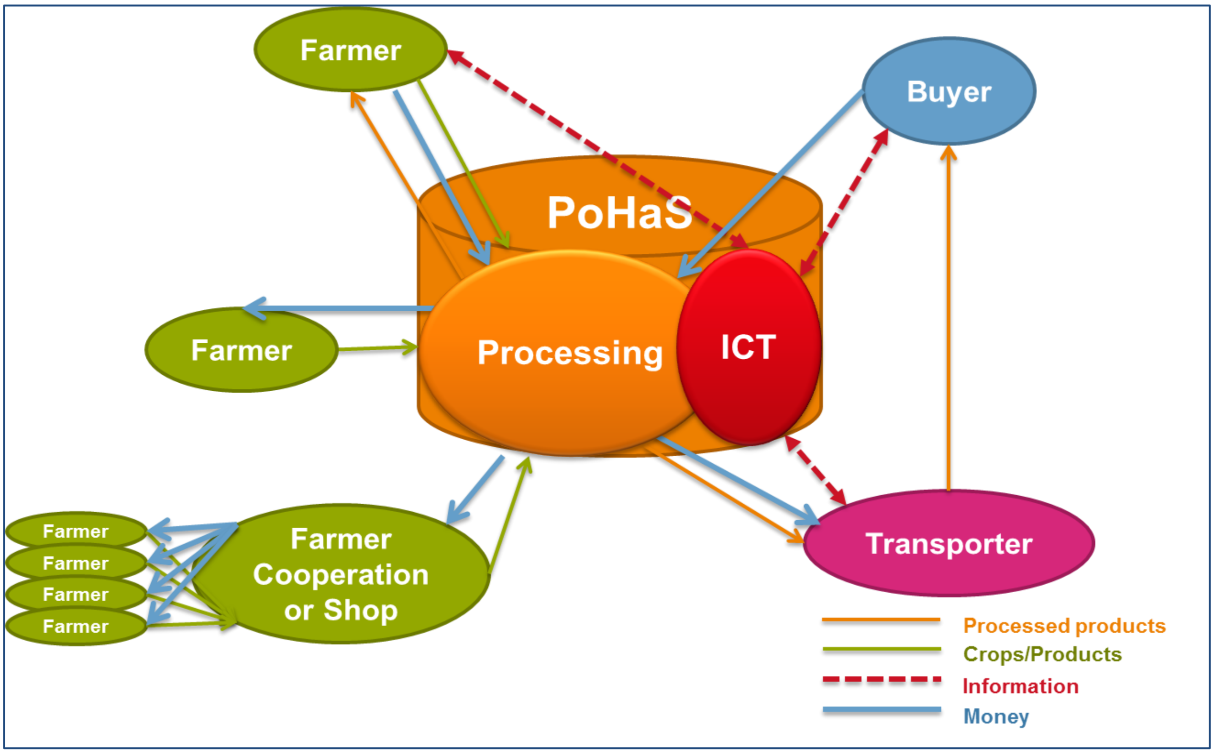


Figure 3: Integral approach as suggested by TNO, called PoHaS

Figure 3 forms the basis for developing the methodology, and will be expanded as a framework, including a number of theoretical concepts. The core of this research concerns the ways in which PoHaS can organise the PHH activities, such as storage, processing and distribution of staple crops throughout the year in the most effective way. I will refer to this aspect as 'governance'. A value chain analysis (VCA) is used as a framework to study the different governance structures that deal with organizing PHH activities. Subsequently, the inclusive innovation framework (IIF) is used, to identify the underlying factors which lead to the successful adoption of inclusive innovations that are specifically targeting the elimination of poverty (Binagwaho & Sachs, 2005). Next, because PoHaS is a concept which is oriented towards the future, it is helpful to shed some light over a solution oriented research paradigm. In essence this subtle conceptual shift means significant implications for phrasing research questions, generating hypotheses, designing research studies, and therefore relating them to research results more relevant to current policy and practice (Robinson & Sirard, 2005). Finally, it is relevant to discuss the theory of technological innovation systems to understand issues from an innovation context.

2.2 Value chain analysis

A value chain analysis (VCA) seeks to capture and describe the complex interactions between firms and the processes required to create and deliver products to the consumers (Webber & Labaste, 2010). In the context of LDCs, VCA is a widely acknowledged framework that can be utilised to strengthen the links in the chain by means of development interventions, that aim to improve the level of opportunities available to the poor (Webber & Labaste, 2010; DFID, 2008). This is not surprising given the large proportion of poor people working in the agriculture sector, who are vulnerable to the consequences of global agro-food restructuring, and through the difficulties they have in gaining market access due to their relatively small scale of farming (Hawkes, 2012).

The analysis could be characterised as where, how, and why value is added and created along the chain and how it could be leveraged for positive change. Another distinctive feature about VCA is that it assumes that value created and added through the chain, is influenced by the interaction between actors during their various activities, and not only by the isolated behaviour of individual actors in that chain (Hawkes, 2012).

These interactions require some level of governance along a value chain. Scholars have defined value chain governance in several ways, for example Kaplinsky and Morris (2012) highlight that ''Value chains are governed when the parameters required for the product, processing, and logistic qualification are set, which have consequences up or down the value chain, encompassing bundles of activities, actors, roles and functions''. The intervention strategy of TNO is limited to three identifiable activities in a VCA: Postharvest handling / storage, processing and distribution, as visualized in figure 4.

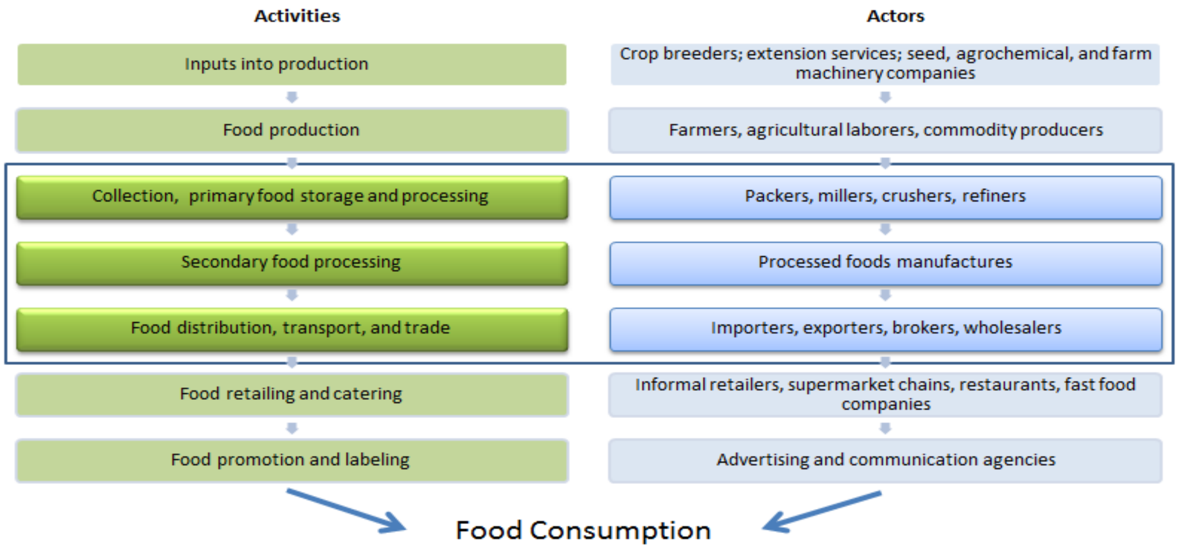


Figure 4: VCA describing the basic actors and related activities, emphasizing three activities that will be organised within PoHaS. Based on (Hawkes & Ruel, 2012)

It is important to discuss how these three parts can be organised. Governance structures can be characterized into 4 categories; market-, balanced-, direct- and the hierarchical based relationship-, (figure 5) that lay emphasis on the allocation of value, uncertain factors and property rights (Dunn, 2005; Sykuta, 2001):

Market relationship: Arms-length transactions in which there are multiple buyers and suppliers. Repeat transactions are possible, but little information is exchanged directly between actors, interactions are limited, and no technical assistance is provided.
Balanced relationship: Both buyers and suppliers have alternatives, that is, a supplier has various buyers and vice versa. There are extensive information flows in both directions, with the buyer often defining the product (its design and technical specifications). Both sides offer skill sets that are hard to substitute, and both are committed to solving problems through negotiation rather than by threat or exit.
Direct based relationship: Direct based relationship can be characterized as a zero-sum game, the buyer or supplier has no inherent interest in the welfare of its input supplier or buyer respectively.

Predefined contracts rely on transparent and easily verified measurement and pricing mechanisms, because there is a relatively low level of trust and asymmetry of information flows. The supplier's options to exit the deal are more restricted than those of the buyer. Therefore, contract based relationships often require incorporating third-party verification or mediation.

Integrated based relationship: Integration of functions that add value within a single company. The supplier is owned by the buyer or vice versa, with the junior firm having limited autonomy to make decisions at a local scale.

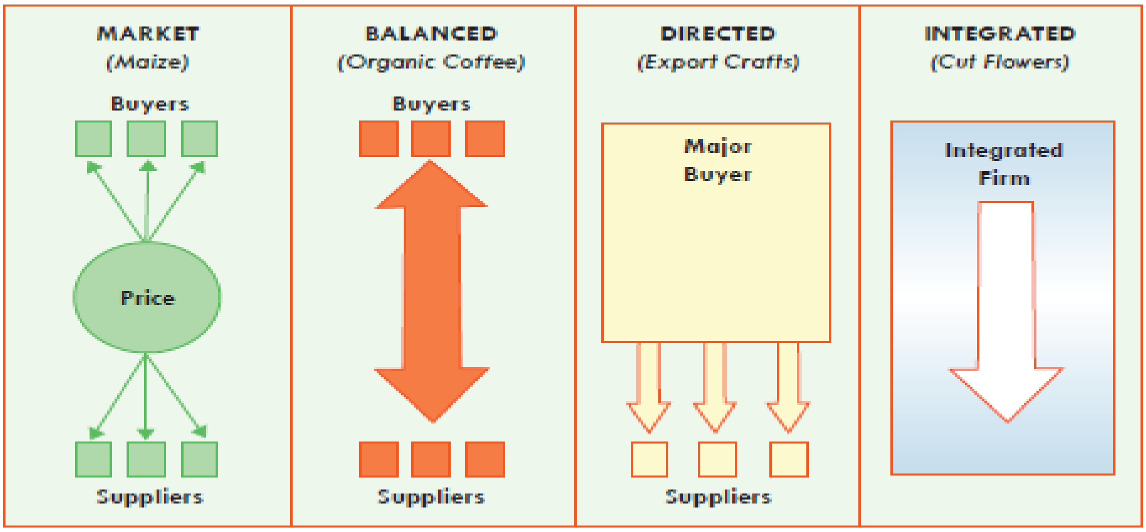


Figure 5: Value chain classifications applied to pro-poor markets (SNV, 2008)

2.3 Inclusive innovation framework

Innovations, especially those that target alleviating poverty and promoting inclusive economic growth are termed as inclusive innovations (Binagwaho & Sachs, 2005). Inclusive economic growth refers to the shift in poverty reduction policies from mere growth to inclusive growth, where marginalized poor people are able to contribute to and benefit from the economic growth (idem).

Inclusive innovation incorporates all forms of innovation related to products, services, business model institutions or supply chains with the only requirement being that they are novel combinations or 'new to the areas context'. Thus, any innovation that is already available in the developed world but is introduced in a novel way to benefit markets in LDCs, is also considered as an inclusive innovation (George, McGahan, & Prabhu, 2012). PoHaS can be considered as an inclusive innovation, since the concept is 'new to the context' and targets poverty alleviation. The concept of PoHaS can be adapted to the local context[3] and aims to increase the access of nutritious food for local consumers and to increase the incomes of small household farmers.

2.4 Solution-oriented approach

The vast majority of past and current basic socio-economic science, and thus also in the field of PHLs and VCA, follow a problem-oriented research paradigm. One of the major conceptual differences between the former and a solution-oriented paradigm, is that problem-oriented research has an orientation to the past, while solution-oriented research looks towards the future (Robinson & Sirard, 2005).

[3] PoHaS project proposal (TNO, 2013)

Solution-oriented research may build upon prior problem-oriented researches and innovative theory-based solutions that extend across disciplines and philosophies. This leads to investigators phrasing their research questions in a forward-viewing manner, for example: 'Does adding multiple products to a centralized processing facility lead to a reduction in PHLs'? The answer to a solution oriented research question can, in contradiction to a problem-oriented research process, be translated directly into an intervention strategy or policy.

During this study very little evidence was found of the existence of solution-oriented research studies with respect to PHLs. This is therefore an area which needs attention, and a forward thinking approach is needed for PoHaS to be successfully adopted and to encourage locals to cut free from previous backward orientation when introducing new initiatives.

Prior problem-oriented research conducted, resulted in identifying the main causes of PHLs in developing countries. The identification of these determinants for PHLs is usually the starting point for development intervention efforts. One method that simply and effectively pinpoints multiple value solutions for a problem is the use of problem and solution trees (PASTs).
PASTs have been extensively used in developing countries, in part because of their role in logical framework analysis (LFA), and their value therefore being widely recognized (AusAID, 2003; DFID, 2002). But also PASTs can be used independently from logical framework analysis, when in combination with a 'best practices' study (Snowdon, Schultz, & Swinburn, 2008; Williams, Bray, Shapiro-Mendoza, Reisz, & Peranteau, 2009).

Therefore it is important to define the challenges encountered in the methodologies by identifying the best form to practice PHL interventions. In general the best practices are those methods or programs that have been found to be successful in accomplishing their goals, and that can be used, or adapted for use, in the circumstances where the intervention will be done (Schorr, 2003). Methods or programs gain such status by being:

- *Measurable*. That means that its goals are clear and that progress towards achieving them can be measured.
- *Notably successful*. The method or program not only gains good results, but makes more progress toward achieving its goals than most others with similar aims.
- *Replicable*. The method or program is structured and documented clearly enough so that it can be replicated, or adapted to your needs in your situation, elsewhere.

These guidelines are helpful when assessing previous studies, to identify the most successful practices of recent PHL interventions in pro-poor agricultural economies.

2.5 Technological innovation system

Many projects in LDCs fail, not for technological or economic reasons, but because the project designers either ignored or oversimplified the social and cultural relationships existing in context to the area of implementation (Murphy, 2001). A broader approach that incorporates the consideration of technical, institutional, social, economic and organizational factors is therefore required. The institutional context around a particular technology is known as the technological innovation system (TIS) (Carlson, 1991) (Hekkert, 2007).

A TIS is defined by a 'network(s) of agents interacting in a specific economic/industrial context under a particular institutional infrastructure or set of infrastructures and is involved in the generation, diffusion, and utilization of technologies' (Carlson, 1991). From this definition, it is apparent that a TIS has three structural elements—actors, networks and institutions. 'Actors' can be public or private, governmental or non-governmental organizations involved in the development, dissemination and adoption of a particular technology (Jacobsson, 2005). 'Networks' are communication channels that facilitate the exchange of information and knowledge amongst actor (North, 1991). 'Institutions' are formal and informal rules that guide the actions and interactions of actors within the innovation system (idem).

A key theoretical aspect is that a TIS performs certain functions, which are essential in achieving its ultimate goal, i.e. development, diffusion and utilization of a technology (figure 6) (idem).
Scholars have argued that TIS functions can be mapped, described and analyzed, and by doing so insights into how TIS generate the enabling environment (idem).

System function	Description	Event types associated
F1. *Entrepreneurial Activities*	At the core of any innovation system are the entrepreneurs. These risk takers exploit business opportunities and perform innovative commercial and/or practice oriented experiments	Projects with a commercial aim, demonstrations, portfolio expansions
F2. *Knowledge Development*	Technological research and development (R&D) are a source of variation in the system and are therefore prerequisites for innovation processes to occur. Non-technological knowledge is also of key importance	Studies, laboratory trials, pilots
F3. *Knowledge Diffusion*	The typical organisational structure of an emergent innovation system is the knowledge network, primarily facilitating information exchange	Conferences, workshops, alliances
F4. *Guidance of the Search*	This system function represents the selection processes necessary to facilitate a convergence in development	Expectations, promises, policy targets, standards, research outcomes
F5. *Market Formation*	New technologies often cannot outperform established ones. In order to stimulate innovation it is necessary to facilitate the creation of (niche) markets, where new technologies have a possibility to grow	Market regulations, tax exemptions
F6. *Resource Mobilisation*	Financial, material and human factors are necessary inputs for all innovation system developments	Subsidies, investments
F7. *Support from Advocacy Coalitions*	The emergence of a new technology often leads to resistance from established actors. In order for an innovation system to develop, actors need to raise a political lobby that counteracts this inertia, and supports the new technology	Lobbies, advice

Figure 6: Functions of a TIS (Roald Suurs et al., 2013)

Understanding the key features, activities and processes of TISs is, therefore, a valuable basis towards understanding the diffusion patterns of new and improved PHH technologies, including PoHaS. This is particularly relevant in LDCs where the capacity to absorb new products and processes is often lacking (Tigabu et al., 2013).

Ch. 3 Methodology

The design of this research study is based upon a case study approach. A case study examines phenomena in their natural setting rather than in an artificially created setting by researchers and explicitly considers the context of the phenomena being studied for the analysis. This research does not aim towards statistical generalisation but rather to gain a deeper understanding of the chances of adoption of PoHaS in the research area, and to investigate how these chances can be increased by developing the existing framework of the PoHaS system. Therefore, the research will predominantly employ qualitative data, through data collection methods. Consecutively, the methods of a value chain analysis, focus group discussions, semi-structured interviews, and desk studies are explained in order to gain a holistic perspective for the development of the new framework, aiming to increase the chances that the PoHaS system is adopted in the research area. Table 2 depicts the research methods and research frameworks that are used to answer the research objectives in this thesis.

Table 2: Methodological framework

Research method (what?)	Place/ people (where?/ who?)	Research framework (how?)	Research objectives (why?)
10 semi-structured interviews / 3 focus group discussions	Gulu and Oyam / actors along the VC	Value Chain Analysis	Governance structures
Literature study	--	Inclusive Innovation Framework	Factors for successful adoption on inclusive innovations
Literature study	--	Solution Oriented Research	Best practices of previous PHL interventions
Semi-structured interviews	Kampala / 17 key informants	Technological Innovation System	Innovation context

3.1 Semi-structured interviews and focus group discussions for mapping actors in VCA

The main objective of using a mapping actors approach is to understand how the different value chains in the Oyam and Gulu district are coordinated and why this governance structure has arisen and evolved. It is important to consider multiple crops, as a specific feature of PoHaS is to handle various crops. This analysis will answer the research question of how PoHaS can be organised from the perspective of a value chain.

Most of the data required for analysing governance was obtained through semi-structured interviews with 10 participants within a value chain and key informants (See annex 2 for the questionnaire). The informants included actors, experts and decision makers in Northern Uganda. In addition to this methodology two (2) focus group discussions were held in the Gulu district and one (1) focus group discussion in the Oyam district.

This methodology corresponds with the idea that a large sample size is not a critical issue for a VCA, but rather the selection of key informants and through the process of gaining an overview of how the local market operates. Key informants are people who have a good understanding of the market situation from their position in the markets value chains (Ferris et al., 2006).

The focus group discussions (FGD) with farmer groups are used to explore the current views on PHH, PHLs interventions and the relations amongst the other actors in the VC. In the selected focus groups we held semi-structured discussions with groups of between 18-51 people, with the aim of getting participants to individually answer the facilitator's questions, but they are also encouraged to talk and interact with each other. This technique is built on the notion that the group interaction encourages respondents to more thoroughly explore and clarify individual and shared perspectives (Morgan & Spanish, 1984).

The interviews were carried out in the field in order to combine them with observations. In this research a form of semi-structured interview is used, in the sense that the researcher establishes the topics to be explored beforehand, but allows the responders to determine the relative importance, and the type of information produced about each topic (Green & Thorogood, 2013). This is contrary to structured interviews, in which all the questions have been formulated exactly and the order they are set in are determined beforehand, and also to in-depth interviews, which completely leaves out the factor of time taken to answer and allows the importance of each issue to be determined by the interviewees (ibid). The use of only questionnaires or structured interviews can easily lead to false conclusions in this early phase of the research process, as it does not allow for a sound understanding of the researched processes.

The first step conducting this analysis is to generate a list of all the actors (within and outside the different value chains) that are potentially able to influence the governance structure (FAO, 2013). This information is to be obtained through interviews with workers of the non-governmental organizations (NGOs) operating at local and national levels ICCO Uganda and AVSI.

The second step is to determine the demand and supply conditions of the value chain to get a good overview of how governance evolves (ibid). This condition is met by constructing a local cropping calendar, based on the extensive knowledge of local extension workers.

In the final step I will determine the dominant coordination arrangements in the different VC as described in the theoretical background. An important aspect to this third step is to analyse under which conditions all of the VC actors participate in a VC. This aspect refers to the inclusive innovation framework and the characteristics of PoHaS. This can be understood by mapping the range of activities that poor participants undertake in a given VC and by identifying the formalities within contracts under which participants operate in the coordination system (e.g. contracting input provision, marketing, certification, contract farming or growth, or final product sales to buyers). It may also include producer-driven formalisations of collective activities (e.g. associations, groups, or other vehicles of collective action) to reduce costs, increase revenues or reduce risks (ibid).

Since the participants in the FGD and some key-informants only speak the local language (Luo and Luganda) there was an interpreter present to overcome the general language problem, but moreover to bridge the cultural assumptions that are embedded in the language the people use. In the set-up of this qualitative VCA we chose to give the interpreter has a more or less independent role, since she already knows the participants from previous extension work, has lead an extended career in areas of research work and furthermore is part of the local cultural arena. Cross-cultural research could influence the validity and reliability of data analysis, therefore we took great care with the selection of the interpreter.

3.2 Literature review on successful inclusive innovations

To identify the factors that determine the degree of successfulness of inclusive innovations, a literature review will be conducted. An attempt will be made to identify the factors that are of significant importance, according to various scholars, and integrate them into a useable framework. With the objective that this framework could eventually serve as a guide for pointing out important strengths and weaknesses to evaluate the inclusiveness of PoHaS.

The guidelines will be compared to determine which factors are most frequently stated in the sources so that it can be determined which factors have the greater importance in determining the eventual degree of successfulness of an innovation.

3.3 Desk study as solution oriented research

The standard method for developing PASTs is modified in this research, tailored to enable the identification of practical solutions to the problem of PHL. Practical solutions are based upon extensive field work conducted by specialist experts, resulting in ‘best practices’ and ‘lessons learned’, being depicted in a solution tree. With respect to the original PASTs, three modifications were made to increase the specific nature and to reduce the time needed to develop a modified solution tree in this thesis:

- The key biological and environmental factors that cause PHLs are applied in the first layer.
- The key socioeconomic factors that hinder the implementation of appropriate PHL technologies are applied in the second layer.
- Best practices and lessons learned that overcome the socioeconomic factors are organized in the third layer.

Splitting the topic over smaller trees can generate additional ideas and ‘floating’ solutions. Those which are not directly linked to a specific problem factor, but could still be relevant in developing intervention strategies (Snowdon, 2008). Studies of best practices and lessons learned to prevent PHLs are carefully selected from several examples of field studies involving; -large scale, -multiple country, -crop, -annual and -partners. In addition, the best examples of practices will be presented of general African technology success stories and up scaling strategies.

3.4 Interviews about Technological innovation system

Understanding the local and national innovation context, will help to understand the factors that are involved regarding the adaptability of PoHaS. Therefore, I will explore the constraints and opportunities of the key features, activities and processes of PHH TIS in the research area by mapping the activities and processes related to the key players, their collaborations and institutions. Data is collected through interviews with a total of 17 key informants. Again a kind of semi-structured interview is used, in a similar way as when determining the VCs, explained in section 2.2. The informants included actors, experts and decision makers of PHH in Uganda (see Annex 3) In addition to the interviews, documents from reports, case studies and policy papers related to PHH in Uganda, are reviewed. The collected data from various sources were compared (triangulated) to ensure reliability.

Ch. 4 Results

4.1 Exploring governance structures

In this section, the process of mapping the various value chains in the research area will be shown, with the actors and associated activities, the demand and supply conditions and the dominant governance structures of the different VCs. Followed by the results of the semi-structured interviews, to aid towards identifying the most suitable governance structure in the adapted PoHaS framework.

4.1.1 Mapping actors and activities in the research area

Figure 7 presents the different actors and their activities in the predominantly examined value chains in the research area. The input phase involves mainly licensed seed companies (e.g. Equator Seeds), who receive foundation seeds from the governmental research institutes (MAAIF and NAAIF[4]). Seed companies provide the seeds for selected farmers, who focus on seed production, and after the seed production, the seed produced are bought back and sold to NGOs. The NGOs then provide seeds, agronomic and PHH training to the other farmers[5].

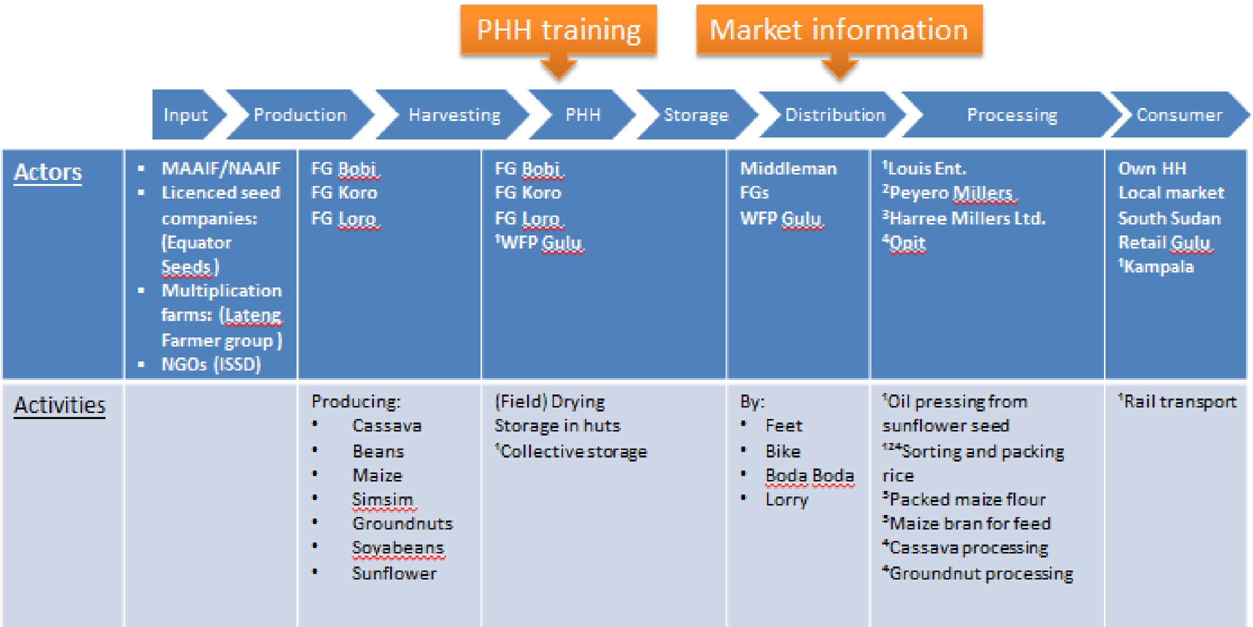


Figure 7: Actors and activities in the Gulu and Oyam district

During the harvest, PHH, storage and distribution phases, farmers[6] sell between 40-80% of their produce to the middlemen or directly to the processors. The remaining part is used for consumption at home. The thereby generated cash is for household (HH) needs. The majority of the produce is sold via the middlemen to the processor, either by the farmers bringing the produce to the village market

[4] Ministry of Agriculture, Animal Industries and Fisheries and the National Agricultural Advisory Services.

[5] 75% of the farmer groups receive support from NGOs and NAADS in the research area.

[6] Farmers are almost all organized in farmer groups (FG), each group has between 15-25 members and only a few farmers are in multiple FGs.

or the middleman collects (bike/boda boda / lorry) the produce in the field (depending on the transportation costs).

Market information is obtained through networking with other farmers on market days (twice a week) and by listening to the local FM radio station[7]. In a few cases[8] there are direct links between the processors and the farmers (vertical integration). A large proportion of the produce is sold on the local market, provided for by the four largest processors situated in the Gulu and Oyam districts. Because of the favorable geographical location of Gulu, South Sudan is an important market source and even buyers from Kampala procure goods in Gulu. According to the FAO in Kampala, if the former rail connection between Gulu and Kenya were made again operational, it would result in increasing (export) market opportunities for processors in Gulu.

Figure 8 shows a simplified VC to give an impression of the importance of the role the different actors in the research area have. In the figure, three colours are used to identify the various roles within the VC; red (input), blue (production, distribution and processing) and green (buyers). The size of the arrows and the oval shapes indicate the importance of that particular actor within the VC.

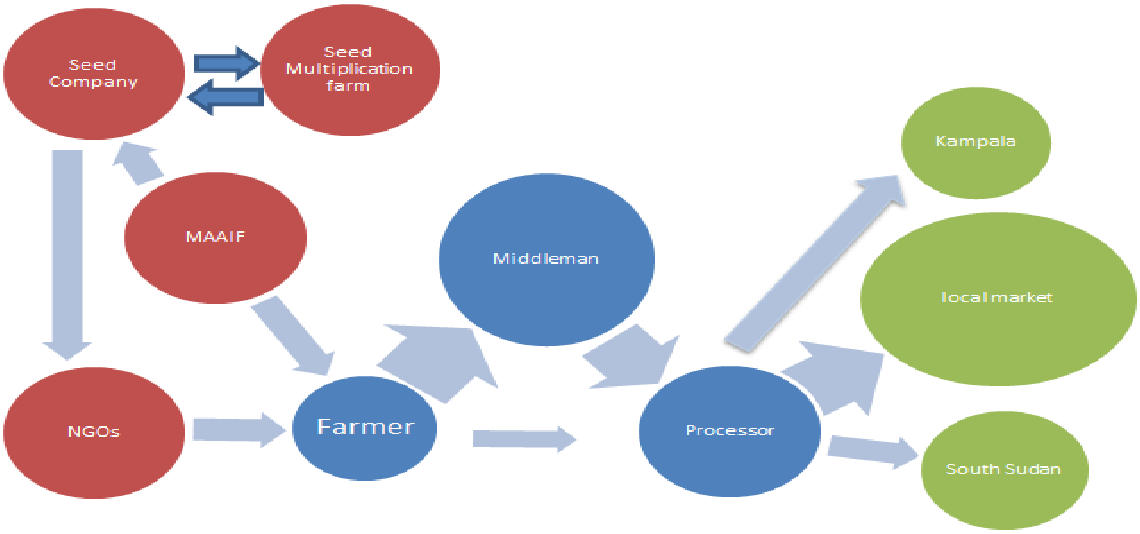


Figure 8: Organizational structure and importance of the actors in the research area

4.1.2. Crop calendar in the research area

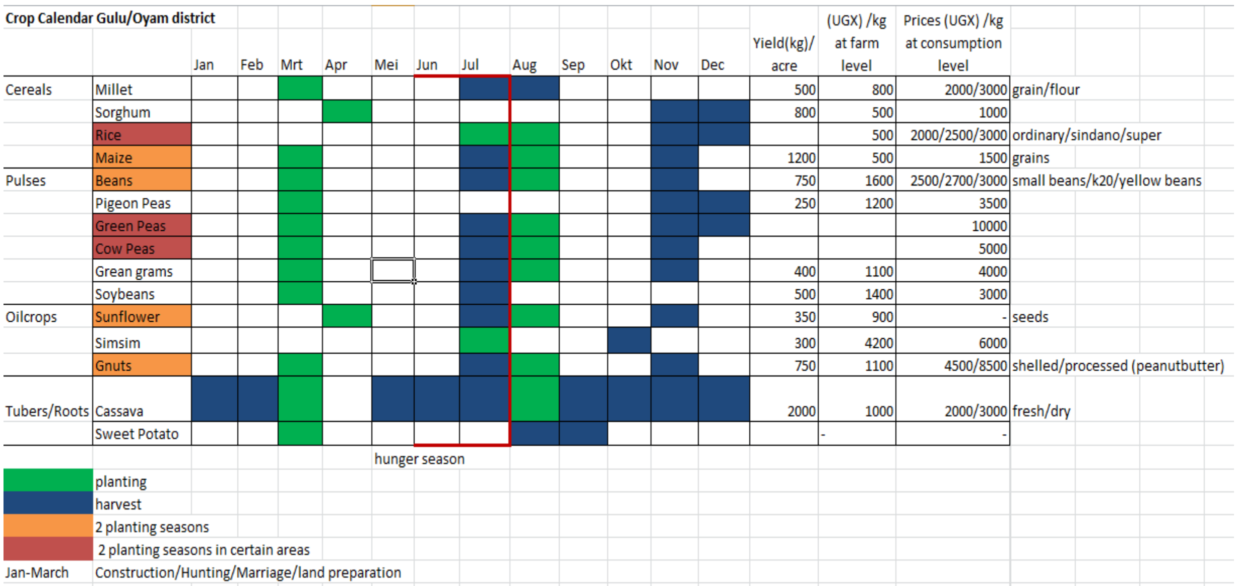
In this section the function of the crop calendar in the bi-modal agricultural value chains in the research area will be explained. Also how they influence the natural supply and demand conditions in the area, whilst considering the local governance structure in place. Figure 9 shows that there are two periods where the harvest of important staple crops takes place for many FGs in the research area. The only staple crop that is available almost all year round for consumption is cassava. The harvested produce, after drying procedures, is stored either in huts, directly consumed by the HH members or sold to a middleman or processor.

[7] The Grameen Foundation broadcast local market price information via local FM radio.

[8] According to the 'Food for progress program' of Louis Ent.

A large[9] proportion of the produce will be sold to the market because the HH needs cash to pay for school fees[10], medical care and other HH necessities. In addition, the FG also need to reserve seeds for the following planting season, and since the availability of quality hybrid seeds provided by NGOs is extremely insecure, quality hybrid seeds can also be purchased on the market, but are in many cases too expensive for the majority of the FGs. Considering the stored produce, there is a conceived average PHL between as much as 20 and 30%.

The storage levels and the extent of PHLs from the stored produce in each FG is case specific and cannot be generalized. But, based upon the extensive local knowledge of extension workers, there is a general impression that there is an excess in the supply of raw produce in the months July, November and December along with associated lower market prices for an individual HH. On the other hand there is greater food insecurity between April and June[11] , with the associated higher market prices and therefore also an increase in bargaining power for the individual HH.



Crop Calendar Gulu/Oyam district		Jan	Feb	Mrt	Apr	Mei	Jun	Jul	Aug	Sep	Okt	Nov	Dec	Yield(kg)/ acre	(UGX) /kg at farm level	Prices (UGX) /kg at consumption level	
Cereals	Millet													500	800	2000/3000	grain/flour
	Sorghum													800	500	1000	
	Rice														500	2000/2500/3000	ordinary/sindano/super
	Maize													1200	500	1500	grains
Pulses	Beans													750	1600	2500/2700/3000	small beans/k20/yellow beans
	Pigeon Peas													250	1200	3500	
	Green Peas															10000	
	Cow Peas															5000	
	Grean grams													400	1100	4000	
	Soybeans													500	1400	3000	
Oilcrops	Sunflower													350	900	-	seeds
	Simsim													300	4200	6000	
	Gnuts													750	1100	4500/8500	shelled/processed (peanutbutter)
Tubers/Roots	Cassava													2000	1000	2000/3000	fresh/dry
	Sweet Potato														-	-	
						hunger season											
	planting																
	harvest																
	2 planting seasons																
	2 planting seasons in certain areas																
Jan-March	Construction/Hunting/Marriage/land preparation																

Figure 9: Crop calendar Gulu/Oyam district

4.1.3 Governance structures

In this section the four largest processors in the research area are introduced, with their actors who set market prices and form quality regulations. Therefore, it is appropriate to first determine the current governance structure based on the perspectives of the processors in the research area. With this information, it is then possible to later discuss an appropriate governance structure for PoHaS in the research area.

Results of open interviews

[9] Between the 40-80% of the produce.

[10] At the time that this interview was taken, it was the first week of the school calendar. This means that the parents has to pay the school fees.

[11] Called in the old days the 'hunger season'.

1. Louis Ent[12].
A family business which produce sunflower oil which is packaged in jerry cans and (un)processed packed rice (bags of 100kg).

Process with suppliers

Rice and sunflower oil is purchased from farmers. Only the 600 registered farmers that attain the 'Food for Progress' program[13] are able to sell to Louis Ent. The advantages for the farmers to participate in this program are as follows; credit inputs by FINCA[14], training in proper agronomic practices, financial management and PHH training. The advantage for Louis Ent., to work in this way is a more stable supply of quality produce. The quality requirements are measured through a products appearance , and by testing the moisture content of both crops. Louis Ent., decrease the price when products are of poor quality as an incentive to farmers to deliver good quality products. Farmers deliver the produce (rice and sunflower seeds) to the processing plant by means of mini-pickup trucks, bicycles or motorcycles. When farmer groups have bulky produce, the processor will then pick up the produce them self, using their own lorry/truck.

The farmers receive a flat price, set by the processor. Farmers have no influence on the price which is mainly based upon the following factors: seasonality (weather influences), the history of the trading relation with the suppliers (e.g. degree of trust) and the demand for the produce.

Process with customers
The then processed products are sold on the local market, used for retail in Gulu, Kampala and South Sudan and the sunflower oil is sold nationally. Louis Ent., say they are satisfied about the high demand for the products (local and national level).

2. Peyero Millers[15]
Is a company which process and pack rice for general consumption. The rice is purchased from 200 farmers in the local area who are in a contract with the company. The processing capacity of Peyero Millers is 5MT/day. In total 80% of the produce is sold to wholesalers and 20% to the local community via rice dealers. There are 12 contracted wholesalers in the area, 8 are situated in Kampala and 4 in Luwero.

3. Harree Millers Ltd[16]
This family company was established in 2009, simply because there was no processor in the area who capable of processing 70MT/year of crop yields produced by their own farm. Working for this company are 2 skilled laborers and 6 unskilled laborers. The main processing stages executed by Harree Millers is the cleaning (input of water), de-hulling, polishing, milling and packaging of maize.

The plant can process 3MT/day of maize kernels into maize flour, with as a result the facility has a 64% utilization rate during the processing. Harree Millers Ltd uses its own trucks to collect the raw produce from the farms and also deliver the maize flour to the buyers.

Process with suppliers

[12] Interview with Oloya (tourist) (CEO) and Alfred One (Business developer manager).
[13] Action plan of WFP Gulu.
[14] Microfinance institution.
[15] Interview with Mr. Okello, manager within Peyero Millers.
[16] Interview with Arvind Devrj, accountant within Harree Millers Ltd in Gulu Town.

The company's main clients are local wholesalers, retailers and importers from South Sudan and Kenya. Harree Millers Ltd., provides the produce on credit to local wholesalers and there are discounts for buying larger quantities. The company works with two pre-contractors who actually source the maize from the Masindi, Hoima, Bweyale, Amuru and Nwoya districts. The contract made with the pre-contractors has fixed agreements on quantity and price and thus the risks are to the contractors. This contract made with the contractors is reviewed every year. The bulk of the purchases are done around harvesting time, because of the lower prices. The main reason for using contractors is because of the language barriers and the skilled labor constraints in the family.

The requirements, related to the grading and inspection of products, for the suppliers are based on testing the moisture content of each gunny bag (130kg). When the moisture content is above 14%, each percent of increase of the moisture content will result in a 1kg loss for the retailer selling the produce (e.g. 15%=129kg; 16%=128kg etc.). In the company there are 3-5% moisture losses. The company does not comply to the East African Grain Standards (EAGS).

Process with customers
There are no specific food safety regulations in place that the company has to comply with in order to sell the produce. Harree can differentiate in the grading size (grade 1, grade 2 and grade 3), to meet the demand of various buyers. There is no contract binding Harree and the buyers of the produce. The price of maize flour is solely determined by the daily market prices, which fluctuates between 600 - 2000 UGX/kg, per annum.

4. Opit[17]
Processes multiple crops; cassava, rice and groundnuts and uses basic PHH machinery. Farmers bring their own raw produce to the company and after processing, will sell their product on the local market themselves or consume it in their household. Farmers will only pay the price per kg. of product that is processed in the facility. There are no quality regulations in place.

4.2 Literature review - Factors which determine levels of success with inclusive innovations

Most of the literature on inclusive innovation primarily focuses on describing the most important characteristics required for the successful adoption of an inclusive innovation. For instance, Mashelkar (2013) suggested a five-point matrix for the qualitative evaluation of inclusive innovations based on the following characteristics: (i) affordable access, (ii) (long-term) sustainable business, (iii) high quality goods and services, (iv) empowerment of the excluded population and (v) significant outreach (Roald Suurs et al., 2013). These five parameters are interdependent of each other.
For example, the scale of production determines the price of the produce; therefore "significant outreach" and "affordable access" are interdependent. And both of these are, of course, linked to "sustainable business". Mashelkar proposes the Five Point Matrix Evaluation as a support tool for determining the success of government lead interventions (Suurs, Diaz Lopez, Boer, Miedema, & Mashelkar, 2013).

[17] Interview with Mr. Opit (CEO).

Anderson and Markides have identified four factors that are important for an inclusive innovation to be successful in LDCs markets (Anderson & Markides, 2012):

- **Affordability**: An innovation needs to be affordable to people with low purchasing power in LDC markets.
- **Availability (Accessibility)**: Availability or accessibility is the extent to which the products or services are available for immediate use with no complications for the customers. This can be challenging in LDCs markets, due to the fragmented nature or the non-existence of distribution channels.
- **Acceptability**: Additionally, the innovation must be accepted by the wider society, which requires compatibility with the existing culture, with its social norms and values. Acceptability by the consumers as well as other members in the value chain for consumption, distribution and sales of a product or service, plays a vital role in the successful adoption of an innovation.
- **Awareness:** Furthermore, people should be made aware of the existence and benefits of the innovation to be successful. Many of the BoP consumers cannot be reached by conventional advertising media, hence novel ways of reaching the customers must be conceived.

Another framework, the concept of appropriate technology, is mostly used in the context of LDCs. From the principles of appropriate technology, it is evident that the concept is in line with the concept of inclusive innovation. The terminologies can be used interchangeably. The innovative technologies need to meet certain criteria to be considered inclusive. The criteria established through the principles of appropriate technology can be listed as (Teitel, 1978):

- **Technical Feasibility**: The innovation must be simple and technically feasible to implement in the context of developing countries. The technology must be durable, easily repairable and adaptable to people in developing countries, given their limited technical knowledge. Preferably, the technology should be developed locally.
- **Social Acceptability**: The technology must be socially acceptable and match cultural practices and norms. It should provide livelihood opportunities to local people and should be ethical.
- **Resources Availability**: The necessary physical resources for the operation of the technology should be sufficiently available at local levels.
- **Economic Affordability**: The innovation must be affordable to low income groups in developing countries. All innovations should aim at being self-sustainable in the long run i.e. an innovation must be aimed towards being distributed via market mechanisms without any charity or any other forms of external financial support.
- **Favourable Institutions**: The innovation must match the institutions present in a particular context and when required, the institutions must also be strengthened to facilitate the innovation.
- **Environmental Sustainability**: The innovation should not put restraint on the environment and should be made in such a way that it is suitably disposable without harming the environment.

4.3 Desk study - Best practices and lessons learned from previous interventions

In this chapter the results of the desktop study about best practices will be shown. These results will then be configured from many different case studies, based on best practices of PHH interventions, into a modified solution tree. Next, best practices will be briefly discussed by means of African technology success stories and up-scaling strategies. To conclude with, an overview of the conceived causes of PHLs and solutions applied by the actors along the different VC, as observed during this research.

4.3.1 Best practices previous PHH interventions

It is important to take into account the substantial difference in causes of PHLs between non-perishable food crops (grains and in a lesser extent pulses) and perishable food crops (fresh fruit and vegetables), see Table 3 for a comparison. Best practices for perishable food crops should not be the same as for non-perishable food crops. Therefore only the socio-economic problems, with regard to PHLs in LDCs, are included in this report, since they occur in both types of crops. The problems that PoHaS are targeting are also mainly rooted in the socio-economic sphere.

Table 3: Comparison between non-perishable and perishable food crop properties and storage regimes (Parfitt et al., 2010).

Non-perishable food crops	Perishable food crops
• harvest mainly seasonal, need for long-term storage storage needs	possibility of permanent or semi-permanent production, short term
• preliminary treatment (except threshing) of the crop before storage exceptional	processing of dried products, an alternative to the shortage of fresh products
• products with low level of moisture content (10-15% or less)	products with high level of moisture in general between 50 and 80%
• small 'fruits' of less than 1g	voluminous and heavy fruits from 5g to 5kg or more
• respiratory activity of stored product very low, heat limited	high or even very high respiratory activity of stored products inducing emission in particular tropical climates
• hard tissues, good protection against injuries	soft tissues, highly vulnerable
• good natural disposition for storage even for several years	products easily perishable, natural disposition for storage between some weeks and several months
• losses during storage mainly from exogenous factors (moisture, insects or rodents)	losses owing partly to endogenous (respiration, transpiration, germination) and to exogenous factors (rot, insects)

Losses of quantity (weight or volume) and quality (altered physical condition or characteristics) can occur at any link in the postharvest chain (Fig 10.). Losses in quantity of the stored produce occur as a result of crops being spilt or leaked out from damaged bags or crates, from theft or from the produce being damaged by pest organisms. Losses in weight may also result from changes in the products moisture content during the storage period. Quality losses occur in various forms; changes in colour, smell, taste and loss of nutritional value (degradation of proteins and vitamins). Often several qualitative changes occur at the same time, usually also in connection with weight losses. See annex 4 and 5 for a complete overview of the identified biological and environmental causes, effects and countermeasures taken for PHLs, respectively non-perishable crops and perishable crops are shown in the three, for this research, relevant stages of the VC.

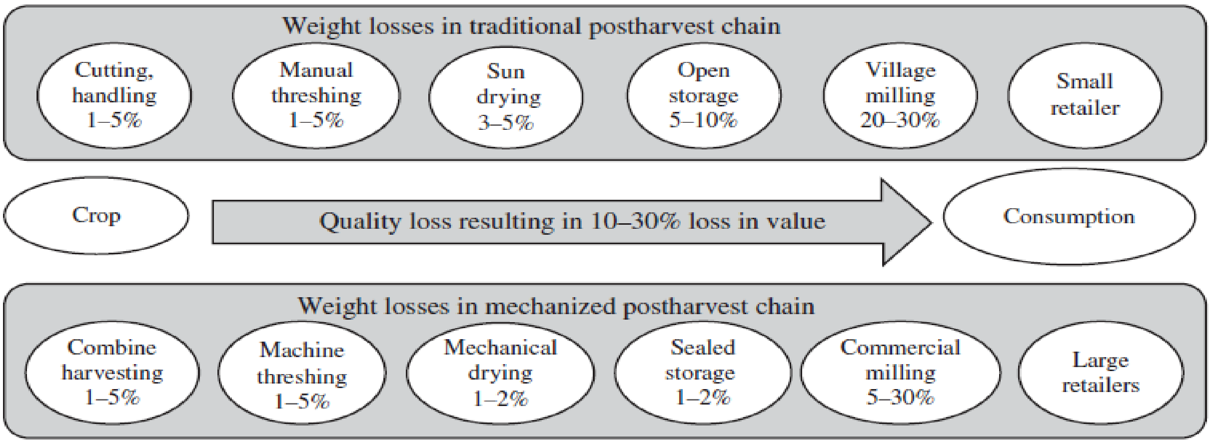


Figure 10: Estimated losses (weight and quality) from the postharvest chain for rice in South Asia (Hodges et al., 2011)

Although the biological and environmental factors that contribute to postharvest losses are well understood (L. C. Kitinoja, M., 2010; Rolle & Mazaud, 2002) and many technologies have been developed to reduce these losses, they have not been implemented due to one or more of the following socioeconomic factors; bad transportation facilities, inadequate marketing systems, government legislation and regulation, unavailability of needed tools and equipment, lack of information and poor maintenance.

Transportation facilities - In most developing countries, roads are not adequate for the proper transport of crops. A problem especially acute in Africa where transport costs can be five times more than those in Asia (Scott, 2009). The majority of producers have small holdings and cannot afford to own their own transport vehicles. In a few cases, marketing organizations and cooperatives have been able to acquire transportation vehicles, but then they are confronted by the poor road conditions (Kader, 2004).

An effective method to overcome this problem is the use of improved containers (perishable crops) and sacks/bags (non-perishable crops) which are stackable and provide protection for the produce during its transportation, where they are subject to poor road conditions, in order to prevent grain and FFV spillage (L. Kitinoja, Saran, Roy, & Kader, 2011).

Plastic crate to transport perishable crops (India)

Improved zero fly bags (Uganda)

Inadequate marketing systems - Farmers can produce large quantities of good-quality grains and FFV, but, if they do not have a dependable, fast, and equitable means of getting such commodities to the consumer, losses will be extensive. This problem exists in many locations within developing countries. It is accentuated by a lack of communication between producers and receivers, and lack of market information sources (Kader, 2004).

To overcome this negative socioeconomic factor it is important to work through local actor groups whenever possible to assess local needs, strengthening marketing capacity (e.g. access to market price information) and market linkages and to develop financing opportunities (e.g. micro-credit). Next to that treat farmers as agri-business people rather than just farmers. When farmers were willing to take on more responsibility for their crops and interact with markets directly, by learning how to handle and sell their produce directly to the retailer, they also gained more of the financial rewards (UNIDO, 2004).

Government legislation and regulation - Regulations covering the proper handling and storage procedures and public health aspects (food safety issues) during production, processing, distribution and marketing are in many cases not enforced properly (Kitinoja, 2010).

Changing policies, processes, institutions and people's incentives and attitudes is a pre-requisite for agricultural transformation. Field assessments have made it clear that training of policy makers and bankers on postharvest management provide a solid basis for decision making on investments and for providing loans in the FFV and grain sector (Kader, 2009).

Unavailability of Required Tools and Equipment - Most of the tools needed for proper PHH, storage, processing and distribution are neither manufactured locally nor imported in sufficient quantity to meet demand. Various governmental regulations in some countries do not permit the direct importation by producers to fulfil their needs (Kitinoja, 2010).

Therefore using tools that are manufactured locally are important as they can be produced at much lower costs than those that are imported, with the added advantage of having more spare parts available in stock. For low-income farmers to adopt new post-harvest management practices and purchase new technology, they must be confident there will be measurable returns on their investment. Sustainability, when adopting a technological innovation depended mostly upon its potential to make profits in the local setting, as they are not subsidy-driven and if necessary they easily could replicate the innovation by using local or readily available materials (Turner et al., 2005).

For example, new technological household storage units for grains (Annex 6) proved to be highly effective (Annex 7) in controlling the moisture content and therefore increased household income by increasing the longevity and insure a quality product for the market, at a, for the farmer, economically favorable time period (Costa, 2014). For perishable crops, the examples are providing shade and the use of low energy consuming cold storage methods. Simple, locally manufactured technology (resp. market umbrellas and clay bricks and sand) is used to provide shade and provide low cost cooling at the stages of produce going from farm to market. Field packing systems alongside the rows of crops during harvesting or in the shade at the side of the field, are also an great means for improvement to reduce costs (eliminating the need for a packinghouse) and wastage (Kitinoja, 2011).

Market umbrella (Ghana)

100 kg size zero energy cool chamber (India)

Lack of information - Most of the people involved directly in PHH, storage, processing and distribution in developing countries have limited knowledge on how to maintain the quality of their agricultural products. There is a lack of:

- local knowledge and technical capacity (few local postharvest trainers exist).
- trustworthiness of the existing postharvest information (misuse is common when recommendations intended for one crop are applied to a different kind of crop).
- understanding by farmers of the required drying or cooling and sorting standards (Hodges, 2011).

Building up the local capacity is broadly acknowledged as being an important factor for improving this. For example, the PHH training of local extension workers (strengthening local institutions) and farmers, network creation (helping members of the value chain meet and get to know each other), resource identification and strengthening of support services (local postharvest suppliers, repair services, engineers, credit). Sending farmers on "educational excursion" to regional or capital city markets helps them to better understand the value chain for their crops. In addition, providing access specifically to women to obtain credit, training and extension services seems to have a strong positive relationship to increased sustainability (Kader, 2009).

Poor Maintenance - In many developing countries, it is common to find facilities that were built a few years ago and are currently “out of order” or not functioning properly because of lack of maintenance and the unavailability of spare parts. This problem is especially true of public-sector facilities (Kader, 2004).

In order to prevent this commonly occurring problem, facilities need to match to local needs (cost, size, scope) and management capabilities and avoid over-building. Large facilities are very difficult for smallholders to manage and the costs are often too high to be profitable.

Empty packinghouse in Indonesia, with no power or water.

A generally important lesson learned in many previously assessed field studies is that projects, aiming to prevent PHLs, should focus to increase the likelihood of sustainable results in the long run. A traditional project has a 2 to 5 years focus period, while a 10 year plan is recommended as a full scale project cycle. Projects that proceed on the results of past projects (and follow up on any evaluation based recommendations) can also achieve good results. An important consideration is that infrastructure development should start early on during the lifetime of the project. The necessary steps (site identification, facility design, feasibility studies, approvals, environmental assessments, construction, equipment procurements, etc) can take a very long time to organize. Project flexibility is thereby a key element to allow for adjustments during implementation (Kitinoja, 2011).

Figure 11 summarizes and depicts the key biological and environmental factors that cause PHLs, in the for this research relevant stages, along the VC. The key socioeconomic factors that hinder the implementation of appropriate PHL based technologies are shown as the second layer in the solution tree. And the best practices and lessons learned towards overcoming these socio-economic factors are organized into the third layer.

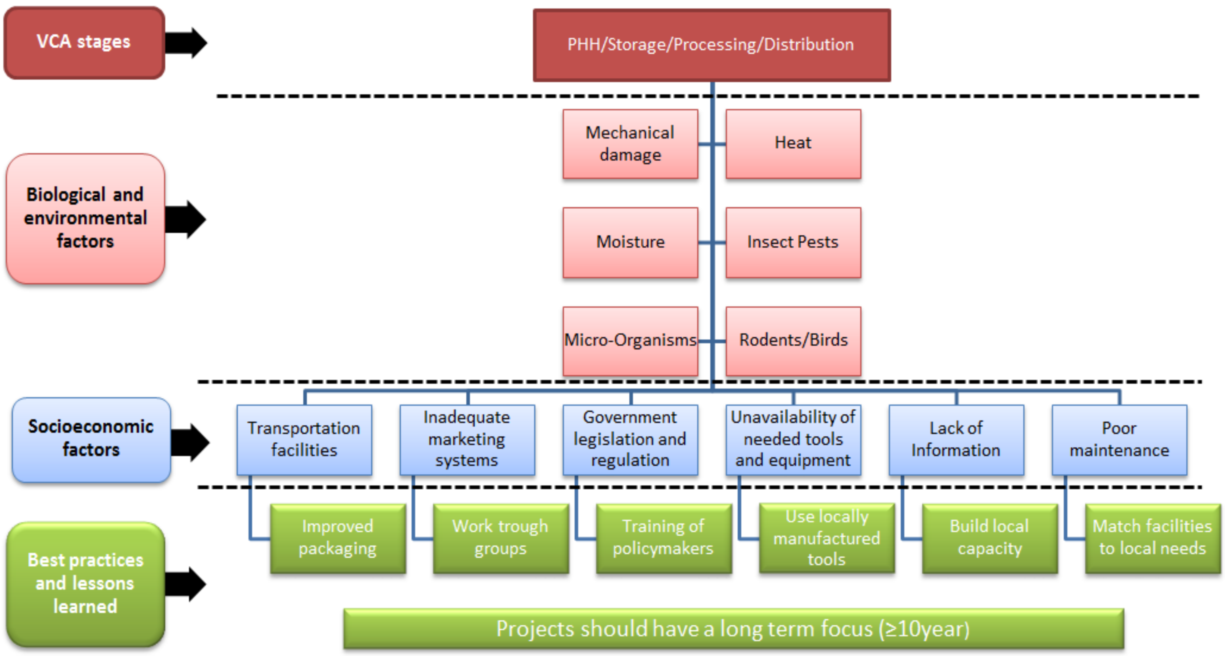


Figure 11: Modified solution tree

4.3.2 Best practices in African technology success stories

Best practices in African technology success stories meet five criteria, according to the International Food Policy Research Institute (Gabre-Madhin & Haggblade, 2004) :

- They have contributed to a growth in productivity ;
- They have resulted in enhanced efficiency and increased farmer incomes;
- They have addressed equity concerns;
- They are sustainable;
- They are scalable.

The *most successful* innovations (in terms of scale and longevity of technology uptake and utilization, and corresponding welfare enhancement) have been innovations targeted at relatively simple applications, supported by relevant and timely institutional and policy innovations[18].

The *least successful* innovations (again, in terms of scale and longevity of technology uptake and utilization, and corresponding welfare enhancement) have been innovations that are knowledge-intensive and require group action to overcome high transaction costs, linked to major institutional flaws[19].

While there is no single strategy for the successful transfer of agricultural innovations that is appropriate to all situations, best practices which will foster success through technology deployment include the following (Bebbington, Merrill-Sands, & Farrington, 1994):

- Careful assessment of the needs of the main users of the proposed technology to ensure that innovations are operationally appropriate to the circumstances of the intended users. Most innovation successes have been those that have addressed existing needs within commodity value chains.
- Communication, coordination, cooperation and interaction among key partners must be strongly supported.

Lessons learned from previous innovation deployments aimed at smallholders in African agriculture include (ibid):

- Technology development and deployment should not skip the field testing and adaptation phases of the development cycle.
- An innovation should not be introduced if it does not conform to the existing sub-sector policy.
- Full reliance on collectives for diffusion of technologies should be avoided.

4.3.3 Best practices up-scaling strategies

For this study it is relevant to examine how the implementation and up-scaling of technological innovations, proceeds in SSA agricultural value chains, since TNO has the ambition to reach at least 100.000 farmers with the concept of PoHaS.

[18] E.g. the cassava grater in West Africa and tissue culture bananas in East Africa.

[19] E.g. soil fertility enhancement practices and integrated pest management.

Three strategies for ‘up’ scaling (replicating similar uses of an innovation over a wider area and ‘out’ scaling (applying an innovation to other problems to broaden its use) of technology innovations, that have emerged during the field studies[20]:

- Spontaneous scaling up and out;
- Scaling up and out after achieving initial local success;
- Development of scaling plans at the projects inception.

In spontaneous scaling processes, there is no explicitly planned or directed intervention to take a successful initiative beyond the project level. Interventions to spread benefits are limited to ensuring that the material requirements are available and accessible. Scaling up happens “naturally,” driven by market forces and informal social structures, or because other organizations take up the innovation in new piloting arrangements.

Under the second strategic option, the innovation may emerge from other organizations, or from the organization itself, but the defining feature is that planning to scale up or out is not initiated unless there is proof of local success.

A third strategy is to plan the scale up initiated from the time the project is conceptualized. This may happen in one of two ways. First, similar to the second model, the aim can be to start small and plan to grow. The key difference with the second model is the planning. The second option in this model is to start big and stay big.

Clearly, the availability of external funds or the capacity of the organization to access external funding should influence the choice of strategy. If funding is available and assured, organizations can pursue the third strategy with confidence. If funding is contingent on demonstration of impact (dependent on evidence of success), then the second model might be appropriate. If funding is not expected after the initial support for one reason or another, the tendency is to let the innovation scale up by itself through spontaneous diffusion. Note, however, that in most cases, irrespective of availability of funds, the first option (spontaneous scaling processes) is pursued by default. Given the stringent needs of sustainable spontaneous scaling processes, it is hardly surprising that few locally successful agricultural innovations have progressed to a larger scale.

While there is no single strategy for the successful scaling of technology innovations, best practices and lessons learned that will foster success in this aspect have innovation plans that include the following:

- Scaling plans should be developed and budgeted up-front. Too often this crucial aspect of the innovation process is ignored.
- Protection of intellectual property rights is crucial to private sector engagement (which is fundamental to scalability).
- Full reliance on NGOs for diffusion of technologies should be avoided.

[20] Meridian Institue, (2009). Science and Innovation for African Agricultural Value Chains, Lessons learned in transfer of technologies to smallholder farmers in sub-Saharan Africa.

NGOs have often relied on participatory approaches, which can often spur innovation uptake at local levels. But these approaches are very difficult and costly to scale up, due to contract design and enforcement problems inherent to rural areas (Meinzen-Dick, Adato, Haddad, & Hazell, 2003).

4.3.4 Conceived causes of PHLs and solutions in the research area

During the three focus group discussions with the farmer groups (FG)[21] in the examined areas, the level of PHLs at the farming stages was estimated between 20-30%. According to the farmers, most of the losses occurred during harvesting, drying, storage and transportation to the village. According to the 4 largest processors in Gulu and Oyam[22] there are only marginal PHLs at the level of processing. The causes of these PHLs are the following.

Harvesting:
Insufficient access to labor, because the members of the FG give priority to their own farms. Delays in the harvesting affect the quality of the produce.

Drying:
Is done on bare ground (risk of contamination with soil bacteria), only the people who can afford them, use tarpaulins. For drying Millet, they often first use cow dung to minimize the amount of sand that gets mixed in with the Millet. The Farmer Group (FG) are forced to mix the correct dried produce with inappropriate dried produce (different moisture content), during the irregular rainy season. The irregular rains delay the drying process and this in turn affects the quality of the produce, subsequently affecting the value price of the produce.

Different crops require different drying methods and duration periods; Maize (Takes 1 month and is dried on the stem), Millet (4 days), Groundnuts (3 days), Simsim (1 month), Beans (3 days), Cassava (1 week), Onions (1 week). Groundnuts in particular have PHLs can reach up to 30% according to the farmers, because after harvest the produce is rooted up and dried in the sun for 2-3 days (possibility through theft).

Storage:
Poor storage in the storage huts; as the conditions are not favorable in terms of capacity (HH members also include livestock, such as goats and chickens, that all live in the same hut as the stored produce), no or poor ventilation (no pallets under the gunny bags), floor is made of mud (termites), roof is made of spear grass (rats) and is prone to fire.
Traditionally the produce was stored in bulk in granaries, this does not happen nowadays because of the high risks of theft and therefore also a lack of trust amongst the FG members. The use of indigenous pest control methods like red chili pepper, and ashes to conserve the produce (for beans, sorghum and maize) can lead to problems occurring when the produce is sold on the market, buyers do not accept or offer a lower price for such a commodity, which then seems contaminated.

Transportation to the village:
Costs of transportation is high and the roads are poor and sometimes inaccessible, especially during rainy season.

[21] Out of the 6 FG (162 members), 89 members attended the focus group discussion in Gulu and Oyam.
[22] Harree (maize flour), Oloya (rice, sunflower), Opit (several crops) and Peyero (rice).

Processing:
The bulk of the processing machinery is of Chinese origin. Instant service and the availability of spare parts are a major problem issue for the processors. Drying installations are sometimes in the right place, but not used because unaffordable running costs due to the high fuel prices.

The conceived solutions of the HH members to overcome the PHLs on a local level are the (financial) access and use of tarpaulins, pallets, improved gunny bags and market information[23]. Processors mainly address the need of PHH training on a HH level, in order to receive a better quality product in processing plant.

4.4 Interviews and literature study - Constraints and opportunities to TIS functions

Another objective of this thesis is to identify the constraints and opportunities of the functioning of the TIS that may influence the developments of the system functions. Table 4, presents the list of such constraints and opportunities identified through a review of the literature on technology, innovation and policy in Uganda, and through interviews with key informants and experts in Kampala.

Table 4: The key constraints and opportunities of the functions of PHH TIS in Uganda.

System functions	Constraints	Opportunities
Entrepreneurial activities	•Lack of road infrastructure •Preference of NGOs or government job	•High level of entrepreneurial skill and attitude •Entry of firms •Constructing PHH technology
Knowledge development	•Lack of sufficient trained man power/low level technical capacity of research institutes •Instable financial budget for research and development •Limited linkage between the private sector and public agencies	•Conducting feasibility studies/market assessments/pilots •Developing new designs/prototypes •Adapting or modifying existing models •Training (of entrepreneurs, technicians, farmers etc.)
Knowledge diffusion	• Lack of inadequate road and telecommunication infrastructure	•Conducting awareness campaigns •Organizing conferences / workshops / seminars / meetings /demonstrations •Setting targets
Guidance of the search	• Lack of designing favourable regulations and policies	•Publicizing feasibility studies and pilots
Market formation	• Corruption	•Sharing the cost of investment (subsidies)
Resource mobilization	•Strict bank procedures •High interest rates •Lack of flexibility	•Providing credit services •Purchase for Progress program

[23] Preferably through a local FM radio station

Advocacy/Legitimacy	•Resource limitations of advocacy groups	

The entrepreneurial activity function is constrained by two key factors, the lack of road infrastructure in rural areas. Because of this, the delivery of harvested crops to the central processing facility in remote areas has been difficult[24]. Another mentioned constraint is that the interviewed actors repeatedly mentioned the fact that college graduates in Uganda often seek white-collar jobs in NGOs or government rather than seeking business opportunities for themselves[25]. On the contrary there is a high level of entrepreneurial skills and attitude prevailing in Uganda, and many young people are currently starting a business in processing and marketing of food products[26][27].

Different initiatives are already undertaken to pilot and test the further developing of a versatile mobile processing unit, mounted on a small truck that can manoeuvre through narrow rural roads. This aims to improve accessibility, affordability and timeliness of milling services for farmers in remote areas[28].

The knowledge development function appears to be blocked by three leading factors. First, it is blocked by the lack of sufficient trained personnel, which led firms such as, Britannia Allied Industries Ltd, Tonnet and East African Basic Foods Ltd, to have low skilled labor to produce high standard food manufacturing machines. Secondly, knowledge development is obstructed by instable budgets, both governmental and by NGOs. For instance, the current war in South Sudan is at the expense of investing in research capacity in the northern region of Uganda [29]. Third, due to limited linkages between the private sector and public agencies there are constraints in building cohesive knowledge capabilities. Many programs are focused at fund acquisition and for this reason international donors and NGOs are considered as key stakeholders. On the other hand there are currently many initiatives from government agencies, research institutes, universities and NGOs that are taking part in feasibility studies, training programs and other projects that enhance the knowledge development of tackling PHLs in Uganda[30].

Knowledge diffusion is also mainly constrained by inadequate road and telecommunication infrastructure. Extension workers cannot easily reach clients who are located deep within villages, as such it has blocked the campaigning effort of improved PHH techniques[31]. However, large scale programs such as the WFP Uganda make use of the community knowledge worker as part of awareness campaigns, to infiltrate in remote areas. The national government and the WFP also set targets to reduce PHLs by 3% per year.

Guidance of the search function is not supported by designing favorable regulations and policies by the national government.

[24] Interview with Alex Fokkens, Dutch private agro processor of the firm Shares.
[25] Interview with Coreen Auma employee at ICCO Uganda and Dr Okasaai program director MAAIF.
[26] Interview with Farid Karama, chairman of the platform of the African Agriculture Academy (AAA) Uganda Ltd.
[27] Interview with Astrid van Rooij, field coordinator ICCO Uganda.
[28] Sasakawa Africa Association (Swiss NGO), historic overview ('96-'07) PHH support.
[29] Interview with Henny Gerner, head of economic affairs in the Embassy Kingdom of the Netherlands.
[30] Based on interviews with the Uganda Industrial Research Institute, Makerere University, ABI Trust/ Trias/Kilimo Trust /African innovation institute (all NGOs), NAADS and 66 assessed PHH projects in Uganda.
[31] Interview with Fiona Byarugaba, CEO Grameen Foundation Uganda.

The government is only addressing the more generic topic agriculture & food and is not mentioning any policy, directive or regulation that favors entrepreneurs or organizations who aim to tackle PHLs[32]. On the contrary, many NGOs conduct and publicize PHH feasibility studies[33].

Market formation is mainly blocked by corruption on all kind of different governmental levels. During empirical observations and interviews with key informants it became clear that companies with close ties to legislative power, have more access to financial resources and could afford well advanced PHH machines. In literature it is found that a better control of corruption will also be associated with rising levels of innovation and entrepreneurship (Anokhin & Schulze, 2009). Nevertheless also identified is a subsidized foundation seed program from the governmental research institutes to local farmers, which forms an important precondition in producing quality and quantity output and thus, a higher household income.

The resource mobilization function is constraint by the strict procedures of financial institutions, which is characterized by complicated and lengthy loan processing. Next to that, the interest rates are on a level of 14% for the best customers at some banks. Because of this, the amount of credit mobilized has not been at the level desired by the Bank of Uganda. However, the WFP implemented a large scale 'purchase for progress' program, which increases the income on household level for farmers and creates incentives to invest in better PHH technologies[34].

Finally, due to a lack of strong unity among companies/NGOs/governmental bodies the function of creating legitimacy has been weakened. Many key informants reported that disagreements on the advocacy agenda and misunderstandings about the prioritization are common among actors who are targeting PHH innovations. This has blocked the emergence of a common voice.

[32] Confirmed by Dr Okasaai program director MAAIF.
[33] Based on desk-research we found 54 NGOs and/or research institutes carrying out PHH feasibility studies in Uganda the last 5 years.
[34] Based on the empirical findings of the NGOs TRIAS, AVSI and the WFP.

Ch. 5 Discussion

In this chapter, the conclusions made from the research are presented in the form of answers to the research questions presented in the first chapter. This is followed by recommendations for adaptations to the PoHaS framework, with the aim of increasing the adoptability of the framework, in the case study areas in an attempt to answer the main research question of this thesis.

5.1 Answering research questions

Q1. What are the lessons learned from previously attempted PHL interventions, in particular from the implementation and up-scaling of technological innovations in SSA?

With successful PHL interventions the possession of several desirable characteristics is a requirement, and these are identified in the literature. Although these characteristics are context dependent, through empirical findings and literature reviews, we identified that PHL interventions should primarily have a long term focus.

Other important lessons learned from previously attempted PHL interventions, taken from the modified solution tree (fig 11) can be summarised as:

- the use of improved packaging material
- the targeting of groups instead of individual HH members
- the training of policy makers
- making use of locally manufactured tools
- building local capacity
- matching the facilities to the local needs.

The most successful innovations in SSA, in terms of scale of application and longevity of the technology uptake and utilization, as well as achieving the corresponding welfare enhancement, have been innovations with relatively simple applications as a target, supported by the application of relevant and timely institutional and policy forming innovations.

To meet the ambitions of TNO, to reach at least 100.000 households, it is advisable to develop and to budget scaling plans beforehand, as all too often this crucial aspect of the innovation process is completely ignored.

Q2. What are the factors involved that would determine the adoptability of PoHaS?

To answer this sub question it is important to understand the characteristics of an inclusive innovation in comparison to the innovation context analyzed by the TIS approach. Mashelkar, and the appropriate technological concept mainly focus on characteristics required to be considered an inclusive innovation, whereas Anderson focuses on how an innovation becomes successful. Whether its adoption is successful or not can be based on observing an acceptable rate of return of the innovation after its purchase, or on the impact it makes. The various characteristics mentioned in the inclusive innovation frameworks of Mashelkar, and of Anderson, the appropriate technological concepts have some commonality between them. In figure 12, an integrated list of all relevant inclusive innovation characteristics are presented.

Mashelkar	Anderson	Appropriate technology	Characteristics of Inclusive Innovation
Affordable Access	Affordability	Economic Affordability	Affordability
	Availability		Availability
	Acceptability	Social Acceptability Favourable Institutions	Acceptability
	Awareness		Awareness
Financial Sustainability		Environmental Sustainability	Sustainability
High Quality Goods and Services		Technical Feasibility Resources Availability	Simplicity
Empowerment of the excluded population			Aspirational
Massive Outreach			Scalability

Figure 12: Aggregating the characteristics of inclusive innovation based on (Anderson & Markides, 2012; Suurs et al., 2013; Teitel, 1978)

The factors that are pointed out most frequently, and could be considered the most important to consider, seem to be ***affordability***, ***acceptability*** (both social and institutional), ***sustainability*** (both environmentally and financially) and ***feasibility*** (both technically and resource availability) which would achieve high quality of goods and services.

The TIS analysis, as shown in the previous section, builds on present knowledge and it is therefore by no means a finished product. In this paper a framework is presented outlining seven key functions, which have a direct impact on the development, diffusion and use of new technologies in the research field of PHH. This section has further attempted to identify and assess some of the possible factors that explain the constraints and opportunities in the Ugandan PHH TIS. The empirical observations suggest that in order to ensure the proper functioning and healthy development of the TIS for PHH in Uganda, policy measures should be targeted at strengthening the weak functions and supporting the strong functions of the TIS. Such steps are important preconditions for achieving widespread diffusion of PHH innovations in Uganda and perhaps in (similar) other LDCs.

The TIS analysis also shows that most of the functions served by the PHH innovation system face obstacles. However, addressing the constraints of every weak function simultaneously may not be feasible. Therefore, I recommend that priorities need to be set, especially addressing the constraints within the ***entrepreneurial activities*** and the ***market formation functions***. This is because these functions play a pivotal role in the buildup and positive functional dynamics of an innovation system in its early stage of development (Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007). Recent efforts, such as the establishment of the test facilities and mobile incubation centers by the Uganda Industrial Research Institute (UIRI) and the Makerere University to encourage business start-ups can be seen as examples of policy interventions to enhance entrepreneurial activities.
Also ***knowledge development*** and ***diffusion*** are key issues, to a concept such as PoHaS, as training is crucial to ensure a degree of progress concerning the efficient running of such a center, with trained personnel who are more capable. Also increasing the potential to spread new insights amongst the

people, and therefore raise awareness and involvement. Focusing on these factors would in turn stimulate entrepreneurship through creating a sound basis for business interactions.

More generally, the TIS and inclusive innovation framework as applied in this thesis have highlighted one major implication for policymaking with respect to supporting the deployment and diffusion of sustainable and inclusive technologies, such as PoHaS, in LDCs. It implies that focused support targeting the inclusiveness of the innovation goes far beyond addressing the technological and economic factors of past approaches. This is important since the major barriers towards the adoption of technologies in LDCs are related to a lack of an enabling business environment, and this can be addressed by means of a proposed inclusive innovation framework and or the functions approach to TIS.

Q3. How should the PoHaS be organized, from a value chain's perspective?

The starting point when giving an explanation about governance structures, in the for this research relevant stages of the VC, is to look at the interactions between farmer groups (FG), processors and distributors. Within the agro-food system of the research area, multiple-transactions are carried out, according to various types of governance structures (e.g. vertical integration, contracts, setting market price). The actor who defines the quality and the price of the produce also ensures the coordination of transactions between the participants.

Following the observations during the interviews with the processors and farmers, it was clear that the processors use their authority and exert power to coordinate the transactions. The choice of governance structure of the individual processor is mainly driven by the availability and quality of the produce and the specific attributes of the transaction (E.g. language problems, labor constraints) in order to minimize the cost of transactions. In general, it can concluded that the transactional parties are largely dependent on each other and on informal agreements, rules (e.g. purchase for progress program), norms and incentives (e.g. price, agronomic- and PHH support) are used to carry out potentially repeated transactions. Even in the case for the processing facility of Opit, who is the only processor that prefers a market governance structure, there is an incentive for farmers to carry out a repeated transaction, which has a stabilizing effect. The identified governance structures for the processors in the research area are synthesized as shown in figure 13.

Processors	VC	Type of GS	Duration (bilateral contract)
Louis Ent.	Sunflower and Rice	Directed	Repeated and limited
Peyero Millers	Rice	Directed	Repeated and limited
Harree Millers Ltd.	Maize	Integrated	Repeated and often unlimited
Opit	Groundnut, cassava and rice,	Market	One shot

Figure 13: Types of governance structures in the research area

At present, there are no solutions available concerning the governance of PoHaS, since the concept contains many characteristics seen in current processors who provide extended services to their suppliers and buyers. Using versatile processing equipment, ICT infrastructure and alternative energy sources, require planning capabilities in order to fully optimize the potential of realizing a concept such as PoHaS. Therefore, well-trained employees are required to serve the needs of PoHaS.

A suggestion is that only a ***directed*** or ***integrated governance structure*** would sufficiently fit the requirements of PoHaS, since they can afford to incorporate the training of employees and don't have to tackle the 'trust' issues, which can be problematic in cooperative or market governance structures.

Q4. What are the key factors that influence technical innovation in the case study area?
During the interviews with the large processors in Gulu town, it was also clear that the instant service and the availability of spare parts is a crucial aspect in the choice of machinery for the entrepreneurs. The availability of well-trained service providers was limited in the research area, therefore the processors stick to proven technologies. This type of reasoning closely relates to the acceptability and need of introducing versatile processing equipment and ICT infrastructure in the research area. During the interviews, processors were restrained and sometimes negative about introducing new technologies, mainly because of the donor driven approach of NGOs. According to the processors the programs of NGOs are often focused on the short term and, for the processors, are not reliable counterparts to do business with. Processors in the research area also point out that the bulk of the PHLs occur on the field or during handling on the farm, and not during the processing stage.

Processing level:

- *The bulk of the processing machinery is of Chinese origin. Instant service and the availability of spare parts are a major problem issue for the processors.*
- *Drying installations are sometimes in the right place, but not used because unaffordable running costs due to the high fuel prices.*

5.2 Recommendations for adaptations to the PoHaS framework

In this sub-chapter, the results obtained to answer the research questions are utilised to help formulate an adapted PoHaS framework. This new framework would then have a higher chance of being adopted in the researches case study areas, and also possibly be expanded into other areas of South Saharan Africa.

5.2.1 New additions to the PoHaS framework

As well as the processing and ICT functions of the original PoHaS framework, additional elements are added to the model to increase its potential for success, in the form of new facilities each with specific operations, but at the same time are closely linked, and aided by an efficient ICT system.

ICT center

The ICT center is the neural network of the new framework, by combining all of the facilities, original and new, ensuring a flow of information between all the elements in the extensive value chain. The PoHaS is central in the value chain network, and is involved in most of the crucial aspects in the VC such as; supply and demand, processing, logistics, transportation planning and maintenance, seed supply/demand and storage, knowledge and innovation, training, research and testing. See figure 14.

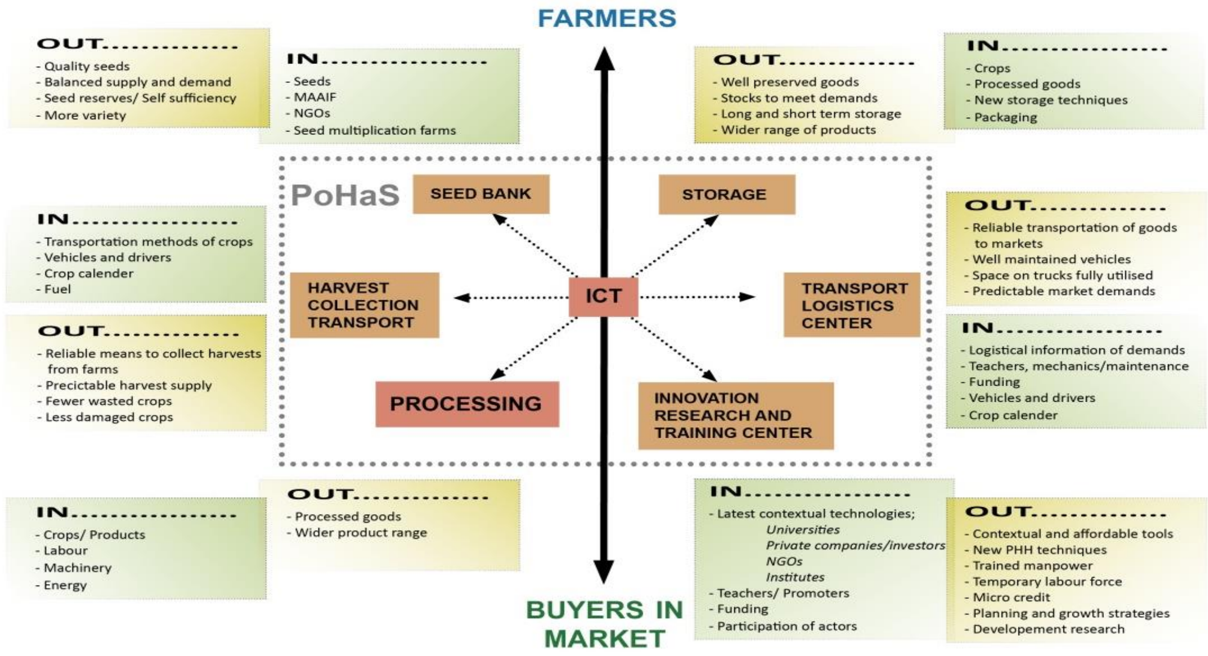


Figure 14: New elements in the adapted PoHas framework – inputs and outputs

Innovation research and training center (IRTC)
A hub of activity where there is research and development, of contextual technologies, farming techniques, farming tools and PHH (processing/drying /storage). The center is also a source of education for all interested, with training (In PHH and use of developed technologies, by experts in the field.

Micro credit is available for farmers, so they have the opportunity to invest in newly developed tools or equipment, with repayment schemes to be able to pay back the loan over time, as the newly purchased items should help to increase the farmer's income by increasing harvest yields, reducing PHL or even to produce a more lucrative crop.

The purchasing of tools and equipment, developed at center and existing can be rented or bought.
These tools are contextual to the local conditions, and the equipment is familiar to the region, so that spare parts and expertise can easily be found, enabling easy maintenance.
Flexible workforces are trained and available to help farmers during peak harvest times, when the workloads are considerably greater, therefore minimizing crop losses at this stage.

The center is linked to all the other facilities in the PoHaS center by the ICT department, to aid in logistics, and to obtain feedback from various actors, to analyze their developed concepts and ideas. The center will work together with NGOs, government, universities, institutes, private companies and the actors in the wider network of VC's. Together they will form a kind of think tank, which forms the initial ideas to be developed at the center.

Storage facilities
More emphasis is made on the variety of storage means, ensuring a better standard overall in preservation of goods. Both short term and long term storage is to be available, which will benefit the logistical aspects of the system.

Transport logistics and maintenance

To be able to maximize the scope of available markets for produce, an efficient transport logistic center is needed. With vehicles and drivers available, and with the means to also hire contractors with their own vehicles, so that market demands can be met. At the same time efficient planning can optimize the available space, reducing overall costs. The new storage facilities will also provide more flexibility in transport options, as there is a bigger time window for the goods to leave the PoHaS center before they spoil. To maximize the use of vehicles, there is a maintenance team on site, trained at the IRTC facility, which can service the vehicles regularly, extending the lifespan of the vehicles and maximizing capacity and availability of vehicle space.

Harvest collection transport logistics

Similar to, and closely linked to the transport logistics, there are vehicles available for the collection of harvests, at the farms. By insuring that all farmer crops are collected shortly after harvest will have a positive effect to minimize losses (theft, weather damage, pests etc). There is also emphasis on sound containers and transportation methods, to minimize damage to crops during the transportation phase to the PoHaS center. A crop calendar is developed at the center, to help farmers to plan their seasonal crops ahead of time to match the market demands as closely as possible, and also to help in the logistical planning of the harvest collection. Again the ICT center functions by allowing a flow of information amongst all actors in the VC's, to enhance the planning capabilities of all the actors involved.

Seed bank

The situation at present, concerning seed production, availability and reserves is far from favorable. Help from third parties, such as NGO's and the MAAIF, is often involved to provide farmers with seeds. In the new PoHaS framework there is a seed storage facility present. With the efficient flow of information, and the feedback loops created by it, the predicting capabilities of all the actors in the VC will increase. It is therefore sensible to provide the resources needed to reach a balanced and sustainable system between market demands and farmer yields, which reduces losses caused by poor planning, and ensure a more stable price for the produce created. The basis of such a situation would be to have all the necessary seeds available to farmers at the correct time. And having a reserve would guarantee stability. The seed reserve would work closely with the seed companies and the seed multiplying farms, NGOs and the MAAIF, but the planning will be done exclusively by the PoHaS.

5.2.2 Value chain interactions with new PoHaS framework

In figure 15 the wider scope of interactions of PoHaS and other actors within the value chain network is shown. The basic PoHaS framework shows the existing flows within the network; crops, processed products, money and information. Due to the addition of the new elements into the framework (seed bank, storage facility, IRTC and harvesting/transport logistics) four new flows have been introduced within the value chain network's interactions. Also the existing flows have been maximized, in particular the flow of information to all actors in the VC, which the ICT facility will provide.

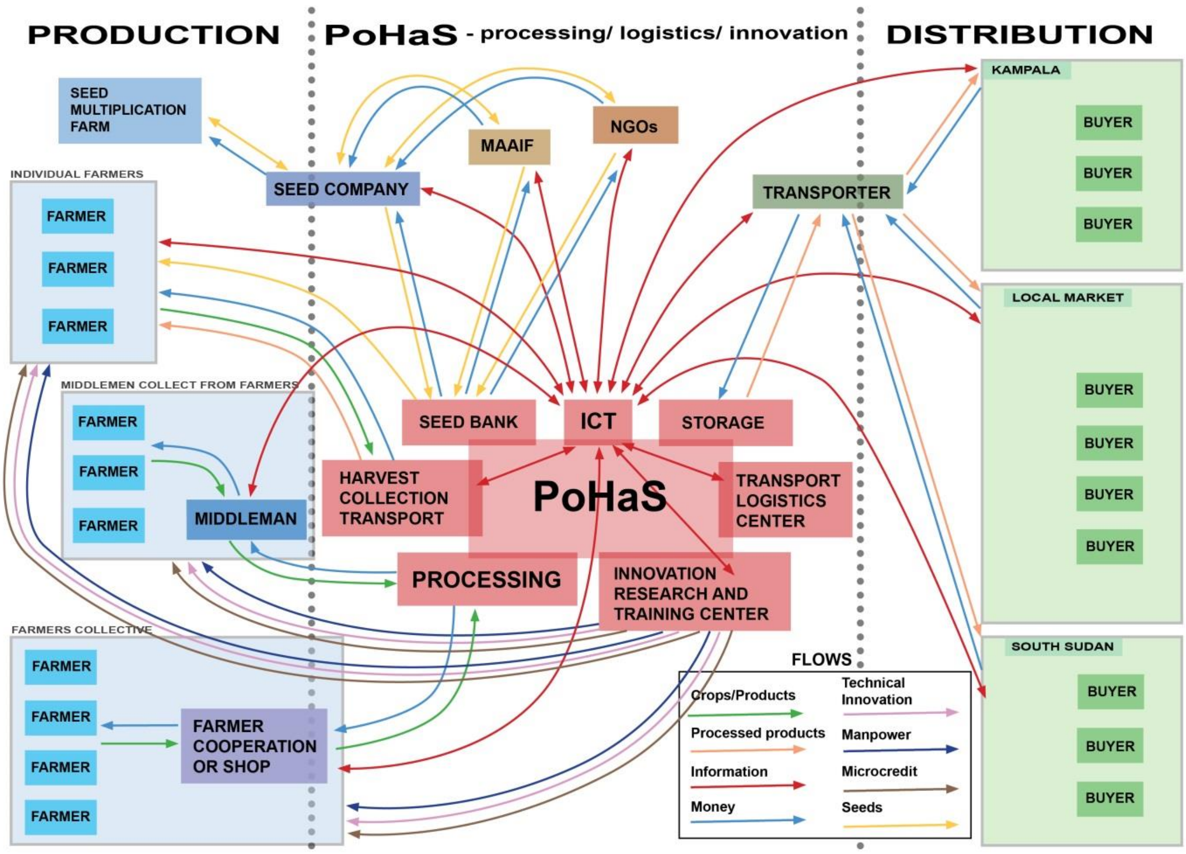


Figure 15: Interactions and flows within extended value chain with the new PoHaS framework.

The new interactions and flows exist of:

1. Technical innovation - Newly developed and tested ideas about PHH and farming techniques, with the resulting tools and equipment realized.

2. Manpower – when the workloads are too high for farmers, due to a small time window for a particular crop to be harvested, they can ask for help at the PoHaS, which will plan together with the farmer and send a relevant workforce team at the relevant time, to aid and assist the farmers in harvesting their crops in time. This way the situation does not occur, where a farmers harvest devalues because it is not brought to the processing facility in time.

3. Micro credit – small loans are made available for farmers to enable them to purchase relevant up to date equipment, which suits the current trends of crop demands.

4. Seeds – All year availability of the correct seeds to meet market demands are available to farmers.

All of the adaptations to PoHaS should lead to a better logistical setup, with information flows that ensure current information on crop demands, food market demands, capacity of farmers, and transport logistics is better communicated between all of the actors in the value chains. Allowing for sustainable situation, where the actors can accurately anticipate trends, and therefore have a better chance to meet the demands. This in turn reduces post-harvest losses as fewer crops are grown out of context to the market demands.

A unified system will in time also increase trust between actors, as more stability will lead to fewer problems and increase value for possible investors and other means of funding for the scheme. At the PoHaS center correct storage requirements can be anticipated for the expected crop yields at harvest time.

Ch. 6 Conclusion

In this research, an attempt was made to analyze the degree of adaptation to the PoHaS framework required, for it to be successfully adopted in the case study areas. A new framework could then be created, based on the original PoHas framework but more contextual to the area it would be (theoretically) executed. If this proves successful the framework could then be applied elsewhere, as the context of the place could be factored into the PoHaS system, to increase chances of being adopted. To meet the research objective, the designed framework needed to be theoretically sound as well as practically useful.

The basic PoHaS framework was developed by TNO, and was still very much in the concept phase, and therefore had never been applied or tested. It therefore took a long time to formulate the research method and find a suitable location to test the framework. Eventually the case study areas in Uganda were selected, but this was already quite far into the thesis.

To prepare for the investigation much background research was done, but it was found that the subject matter was not thoroughly covered in the literature, but it was still possible to find enough suitable methodologies to help develop the PoHaS framework further. Four methodologies were selected for the research to investigate the agricultural economy in the context of the case study areas. The four methodologies were applied successfully in the case study areas of Gulu and Oyam, near to Kampala in Uganda, and the results were both relevant and revealing.

'Best Practices' gave good insights into what to do or not to do when applying PHL interventions in the region of Sub-Saharan Africa, which could be factored in, to develop the PoHaS framework further. The 'Inclusive Innovation Framework' resulted in several guidelines for identifying which factors to pay attention to with inclusive innovations, which determine their successful implementation in developing countries. These were then compared and factors that were identified most frequently amongst the various guidelines gave an indication to which factors should be given the most priority in the case of developing the PoHaS framework.

The 'Value Chain Analysis' gave a good overview of the case study areas agricultural economy structure and the forms of governance applied within it. The value chains were determined, involving all the actors in the VC and how they interacted with each other. These value chains were combined and further extended to include more elements of the food production system. These were integrated with the PoHaS framework, where the PoHaS is the main element in the value chain with the added role as the control centre of various chains, concerning the planning of activities, identifying and predicting market demands through regular communication with markets, processing the crops, logistics, transportation planning and maintenance, seed supply/demand and storage, knowledge and innovation concerning farm equipment and PHH techniques, training, advising, financial aid in the form of micro-credit to enable and stimulate entrepreneurship , research and testing.

Finally the 'Technical Innovation System' was determined to reveal the 'constraints' and 'opportunities' for technical innovation in the case study areas. It was concluded that entrepreneurial activities, market formation, knowledge development and knowledge diffusion were the main factors to focus on in the case study areas as they would have the greatest positive impact on technical innovation and economic growth.

The opportunities identified for these factors were then also integrated into the PoHaS framework, and the constraints were taken into account and to some degree eliminated in the new framework.

The applied methodologies led to results which successfully answered to all of the research questions, and through this the PoHaS framework could be adapted, relatively successful, to fit the context of the case study areas and hence, increase its chances of successful adoption.

With all the extra roles the PoHaS, with a complete overview of all activities, could therefore ensure proper coordination between all the actors in the VCs and a smooth flow of goods from the production, to processing and storage, to consumption. The market demands can be met with a higher degree of accuracy, reducing risks of over-supply, and the resulting devaluation of the products.

The extensive ICT network enables efficient exchange of information amongst the actors in the VCs and the PoHaS, enabling the PoHaS to make projections on supply and demand, organizing all the required activities required to meet these demands, and to identify new potential markets to stimulate growth in a sustainable way, in which they will turn vastly increasing the chances of economic success.

Resulting in a food chain that is stable and sustainable, which optimizes the running of activities and use of resources by; lowering crop losses, improving PHH techniques and equipment, reducing the chances of corruption, matching supply with demand and maximizing transport logistics.

The stabile growth will also increase levels of trust amongst actors in the VCs, and create a safer environment for potential investors, reducing the need to depend on NGOs and other forms of external help to function properly.

Finally the new PoHaS framework also has emphasis on contextual innovation, and the relevant education and training involved to properly apply the innovations. This will enrich the VC, as the capacity of the actors in the VC will have increased opportunities, and this would create a way for the poor to enable themselves to improve their lives, and have a positive impact on levels of poverty in the area the new framework is applied.

Looking back on the factors that determine the degree of success on an inclusive innovation, it is evident that the newly proposed PoHaS framework would theoretically adhere to the factors highlighted in the several guidelines with inclusive innovations, which determine their successful implementation in developing countries. It can therefore be concluded that the new framework would in theory therefore have a better chance of being adopted in the selected locations.

Through applying the methodologies in this research, an Inclusive Innovation Contextual Analytical Framework was developed, described, and demonstrated, paying extra attention to balance the theoretical and practical relevance of the research. Nevertheless, it has to be mentioned that the new PoHaS framework proposed in this research is a first attempt to make a framework for analyzing inclusive innovation context and might need further refinements in both theoretical and practical aspects.

Based on the lessons learned and best practices of previous PHL interventions and the implementation and up-scaling strategies of technologies in SSA, the carefully selected information for this research was synthesized and developed into a successful method for determining the PHL challenges which in turn helped to develop the new PoHaS framework.

Conducting this research revealed that the governance structure is limited to three identified activities, which were determined in the VCA, these are: Postharvest handling and storage, processing and distribution, as visualized in figure 5. It was important to discover how these three segments could be organised, whether through producer organisation- (PO), contract- or hierarchical based relationships, and showed that the scope of the PoHaS framework could be enlarged to include more functions than these three main activities, to create a more desirable, multiple value chain situation.

The main problems encountered during this research

Due to the slow start with this investigation, in developing a research methodology to test and improve a concept that was still in its very early stage of development, there was no clear indication for a possible location for the case studies, and how to approach the research problem.

Because of this the conducting of the various methodologies had to been done in the latter stages of the thesis, and therefore the results from interviews with actors in the VC may not have been as thorough or consistent as would be desired. There is high probability of insufficient data on each actor level of the value chain, and that many assumptions on PHLs had to be made. Therefore, the results in this study must be interpreted with great caution.

It is also very well addressed in the literature that PHLs interventions have to be planned within the context of the relevant value chain. With respect to the former, it would be challenging to develop an intervention strategy that is generalizable to value chains elsewhere.

Finally, in this research there is an emphasis on the multi-crop perspective as specified in PoHaS. A VCA typically involves a single-crop, and fails to take into account the other value chains operating alongside it and so does not consider the cross linkages between the other value chains, which is a key distinction of the PoHaS framework. Therefore it was difficult to obtain proper data, through the novel nature of the PoHaS concept.

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Annex 1: Matrix of processes that might be applied to certain (groups of) crops[35]

Process	wash	De-hul	Peel cut	mill	dry	cook	Fry roast	Press (oil)	Ster./ past.	pack	cool	freeze	store
Crops													
Staple carbohydr.	+		+	+/-	+/-	+/-	+/-			+	+/-	fries	+
Cassava													
S/potato													
Staple seeds	+/-	+		+/-	+	h		+/-		+	+/-		+
Maize				+									
Rice													
Millet													
Simsim													
Sorghum													
Hulled seeds		+		+/-	+/-			+/-		+			+
Sunflower													
Vegetable proteins	+/-	+/-		+/-		h				+	+/-	+/-	+
G/nuts							+	+/-					
Beans													
P. Pigeon													
Soybeans													
C/peas													
Vegetables	+		+/-		+/-	h			+/-	+/-	+/-	+/-	+/-
Fruits	+		+/-		+/-					+/-	+/-	+/-	+/-

+: mostly done

+/-: sometimes, depending on the application

h: at consumption

Description type of equipment expected to be available in SSA:

Wash: Water bins, where products are put in, stirring and then lift products out (sieve basket). Much handwork
Dehul: Simple crushing equipment followed by wind sifting of sieving
Peel / cut: Abrasive peelers, automatic or hand cutting knifes or cutting blocks
Mill: Simple rotating knifes or other milling equipment, standard
Dry: Solar dryers, products spread out in the sun (with rain cover), drying cabinets with fuel for heating, more advanced: moving belts with products and warm air over/through the belt
Cook: Water bins, heated by fuel burners (look at heat transfer / energy efficiency), where products are put in, stirring and then lift products out (sieve basket). Much handwork
Fry / roast: In hot air ovens or oil fryers, pans fired with fuel
Sterilize / pasteurize: Submerge products during a certain time in hot water bins, heated by fuel burners and then lift products out (sieve basket). Much handwork
Pack: In containers, crates, plastic bags, eventually vacuumed and sealed
Cool: In cold cells, by cooling machinery, also thing of under the ground storage, cooling by local water, shading, venting at night etc.
Freeze: In cooling cells, freezing machinery obligatory, normally based on electricity
Store: Mostly as cold as possible, like cooling cells. Avert mice, rats etc..

[35] Based on interviews with field experts of TNO

Annex 2: Questionnaire based upon FAO, 2013

Pre-Production
1- **Importance of the crop**. What is the relative importance of the crop (number of producers, amount produced, area of production, value)?
2- **Governmental policies**. Are there any laws, regulations, incentives or disincentives related to producing or marketing the crop? (e.g., existing price supports or controls, banned pesticides or residue limits)
3- **Relevant institutions**. Are there any organizations involved in projects related to production or marketing the crop? What are the goals of the projects? How many people are participating?
4- **Facilitating services**. What services are available to producers and marketers (for example: credit, inputs, technical advice, subsidies)?
5- **Producer/shipper organizations**. Are there any producer or marketer organizations involved with the crop? What benefits or services do they provide to participants? At what cost?
6- **Environmental conditions**. Does the local climate, soils or other factors limit the quality of production? Are the cultivars produced appropriate for the location?
7- **Availability of planting materials**. Are seeds or planting materials of adequate quality? Can growers obtain adequate supplies when needed?
Production
8- **Farmers' general cultural practices**. Do any farming practices in use have an effect on produce quality (irrigation, weed control, fertilization practices, field sanitation)?
9- **Pests and diseases**. Are there any insects, fungi, bacteria, weeds or other pests present that affect the quality of produce?
10- **Pre-harvest treatments**. What kinds of pre-harvest treatments might affect postharvest quality (such as use of pesticides, pruning practices, thinning)?
11- **Production costs**. Estimate the total cost of production (inputs, labor, rent, etc). What are the costs of any proposed alternative methods?
Postharvest
12- **Harvest**. When and how is produce harvested? by whom? at what time of day? Why? What sort of containers are used? Is the produce harvested at the proper maturity for the intended market?
13- **Grading and inspection**. How is produce sorted? by whom? Does value (price) change as quality/size grades change? Do local, regional or national standards (voluntary or mandatory) exist for inspection? What happens to culled produce?
14- **Postharvest treatments**. What kinds of postharvest treatments are used? (Describe any curing practices, cleaning, trimming, hot water dips, etc.) Are treatments appropriate for the product?
15- **Packaging**. How is produced packed for transport and storage? What kind of packages are used? Are packages appropriate for the product? Can they be reused or recycled?
16- **Cooling**. When and how is produce cooled? To what temperature? Using which method(s)? Are methods appropriate for the product?
17- **Storage**. Where and for how long is produce stored? In what type of storage facility? Under what conditions (packaging, temperature, RH, physical setting, hygiene, inspections, etc.)?
18- **Transport**. How and for what distance is produce transported? In what type of vehicle? How many times is produce transported? How is produce loaded and unloaded? In what condition are the roads? Are there seasonal access problems due to poor road conditions?
19- **Delays/ waiting**. Are there any delays during handling? How long and under what conditions (temperature, RH, physical setting) does produce wait between steps?
20- **Other handling**. What other types of handling does the produce undergo? Is there sufficient labor available? Is the labor force well trained for proper handling from harvest through transport? Would alternative handling methods reduce losses? Would these methods require new workers or displace current workers?
21- **Agro-processing**. How is produce processed (methods, processing steps) and to what kinds of products? How much value is added? Are sufficient facilities, equipment, fuel, packaging materials and labor available for processing? Is there consumer demand for processed products?
Marketing
22- **Market intermediaries**. Who are the handlers of the crop between producers and consumers? How long do they have control of produce and how do they handle it? Who is responsible for losses /who suffers financially? Is produce handled on consignment; marketed via direct sales; move through wholesalers?

23- **Market information**. Do handlers and marketers have access to current prices and volumes in order to plan their marketing strategies? Who does the recordkeeping? Is information accurate, reliable, timely, useful to decision makers?
24- **Consumer demand**. Do consumers have specific preferences for produce sizes, flavors, colors, maturities, quality grades, packages types, package sizes or other characteristics? Are there any signs of unmet demand and/or over-supply? How do consumers react to the use of postharvest treatments (pesticides, irradiation, coatings, etc.) or certain packaging methods (plastic, styro-foam, recyclables)?
25- **Exports**. Is this commodity produced for export? What are the specific requirements for export (regulations of importing country with respect to grades, packaging, pest control, etc.)?
26- **Marketing costs**. Estimate the total marketing costs for the crop (inputs and labor for harvest, packaging, grading, transport, storage, processing, etc.). What are the costs for any alternative handling or marketing methods proposed? Do handlers/marketers have access to credit? Are prevailing market interest rates at a level that allows the borrower to repay the loan and still make a profit? Is supporting infrastructure adequate (roads, marketing facilities, management skills of staff, communication systems such as telephone, FAX, e-mail services)?

Annex 3: Key informants and experts in the field of PHH

Date	Time	Organization/institution/enterprise	Location	Contact person	Contact details
10-02-2014	10-11 am	AAA Academy	UMA Showground, behind Pride Microfinance at UWE House	Farid Karama	0752-584069
		Uganda Small Scale Industries Association			
		Uganda Industrial Research Institute	Charles …		
11-02-2014	10-11 am	Shares! (private company)	Box 3, Mukono	Alex Fokkens	0772-395947
	14-15 pm	EKN	Rwenzori Court	Henny Gerner	0777-808790
		Abitrust	UEDCL Tower, Nakasero Tower	Owen Mugume Timbitwire	Owen.Mugume@abitrust.com +256312351600
12-02-2014	09-10 am	Makerere University, Department of Food Science and Technology	MUK campus	Dr Agnes Namutebi	0712-958736
	11-12 am	Trias (with Agriterra in PHH program)	Kansanga	Paul Allertz	paul.allertz@triasngo.be 0794-233433
	16-17 pm	TetraTech (implementer for Feed the Future)	Plot 15, Clement Hill Road	Erik Derks	0772-770121
13-02-2014		Grameen Foundation	6th floor, Lourdel Towers, plot 1 Lourdel Rd, Nakasero	Fiona Byarugaba	fbyarugaba@grameenfoundation.org +256772712985
		WFP	Clement Hill Rd, Nakasero	Germain Koffi Akoubia/ Vincent Kiwanuka	Vincent.Kiwanuka@wfp.org +256(0)772500688
		FitUganda/Infotrade	Plot 175, Kyadondo Road	Enoth Mbeine	enoth@fituganda.com +256(0)752851166
	17-19 pm	Debriefing (include IFDC/ISSD/APF/ICCO)	ISSD/IFDC (tbc)	David Slane	dslane@ifdc.org
14-02	Ministry of Agriculture, Animal Industries and Fisheries (MAAIF)	Nakasero	Dr Okasaai	0772-589642 (sent sms)	Ministry of Agriculture, Animal Industries and Fisheries (MAAIF)
	Tonnet Agro Engineering	Gayaza Rds		0772-413754/0414373	Tonnet Agro Engineering

Annex 4: Sources of PHLs in non-perishable crops, adapted from (Gwinner, Harnisch, & Mück, 1990; Hodges, 2011)

Problems	Causes	Effect	Countermeasures
Mechanical Damage	- Incorrect harvesting methods - Poor handling, threshing, shelling, cleaning, sorting or drying - Bad transport and loading practices (e.g. use of hooks)	- Losses in weight -Losses in quality (germination power, nutritional value) -increased vulnerability to infestation from insect pests, fungi and rodents	- Pay attention to maximum temperatures when drying - Use safe techniques in harvesting, transport, processing and storage - Take care when handling bags - Repair or replace damaged bags - Do not use hooks to carry bags - Repair pallets
Heat	- Unsuitable storage structures (false location, insufficient shade and ventilation facilities, lack of heat insulation) - Mass reproduction of storage pests and fungi - Lack of aeration of store - High moisture content of the grain	- Losses in weight -Losses in quality (nutritional value, germination power) -Good conditions for pest development -Condensation with subsequent development of fungi	- Build suitable storage structures - Provide shade for stores or silos (e.g. by means of wide eaves or shading trees) - Keep temperatures as low as possible (aerate storage facility) - Conduct treatments for pest control - Store bags on pallets in order to improve aeration - Maintain spaces around all bag stacks
Moisture	- Insufficient drying before storage - High relative humidity - Constructional faults and damage to the store (unsuitable materials, unsealed floor, walls and roof, holes, gaps, etc.) - Imbalances in temperature (e.g. day/night) in storage facility with subsequent condensation - Produce stored on the floor or touching the walls - Mass reproduction of pests	- Losses in quality - Losses in weight -Development of fungi and formation of mycotoxins -improved conditions for the development of pests -Swelling and germination of seeds - Damage to storage structures	- Dry produce sufficiently before storage - Repair and seal storage facility - Keep relative humidity as low as possible in storage facility (perform controlled ventilation) - Store bags on pallets - Maintain spaces of I m around all bag stacks - Conduct pest control treatments - Avoid temperature fluctuations (day/night) in store by means of shade and ventilation
Insect Pests	- introduction of infested lots - Cross infestation from neighbouring lots or stores - Migration from waste or rubbish - Hiding places in stores (cracks, fissures) - Use of infested bags	- Losses in weight - Losses in quality (impurities such as droppings, cocoons and parts of insects, reduction of nutritional value, reduction in germination power)	- Harvest at the right time - Choose tolerant varieties - Keep means of transportation clean - Remove infested cobs, panicles or pods before storage - Ensure that produce is dry before storing - Prevent pest introduction by checking for infestation before storing - Clean the store daily - Keep the temperature and relative humidity as low as possible (perform controlled ventilation)

		- increase of temperature and moisture	- Prevent any pest infiltration by sealing the store (windows, doors, ventilation facilities; e.g. with the use of insect gauze) - Repair any damage to the store immediately - Store old and new lots separately - Clean empty bags thoroughly and treat them against insects if necessary - Perform pest control treatments - Rotate stocks: 'first in - first out'
Micro-organisms	- High moisture content of stored produce - High relative humidity in store - Condensation - Humidity and moisture produced by insects	- Loss of quality (smell, taste, colour, nutritional value, germination power) - Formation of mycotoxins - Slight loss of weight (mould) - Further increase in temperature and moisture - Further condensation	- Dry produce sufficiently before storage - Never allowing grain or cobs to have direct contact with the soil during drying and using tarpaulins to reduce the risk of contamination and to provide cover when exposed during damp weather . - Keeping animals away - Keep relative humidity as low as possible in storage facility (perform controlled ventilation) - Store bags on pallets - Maintain spaces of around all stacks - Conduct pest control treatments
Rodents	- Penetration through badly closing doors, windows, ventilation openings, holes - Lack of barriers - Lack of hygiene in store and surrounding area (possible hiding and breeding places)	- Loss of weight - High losses in quality due to contamination of produce with faeces and urine - Contamination of produce with pathogenic agents (typhoid, rabies, hepatitis, plague, etc.) - Damage of material and facilities (bags, doors, electric cables)	- Prevent entry of rodents by sealing store rat-proof - Keep store and surrounding area clean - Place traps - Carry out rodent control measures

Annex 5: Sources of PHLs in perishable crops, adapted from (Kader, 2003).

Problems	Causes	Effect	Countermeasures
Mechanical Damage	- Incorrect harvesting methods - Poor handling, cooling, storage or distribution - Bad transport and loading practices	- Losses in weight -Losses in quality (germination power, nutritional value) -increased vulnerability to infestation from insect pests, fungi and rodents	- Use safe techniques in harvesting, transport, processing and storage - Take care when handling crates - Repair or replace damaged crates
Heat	- Unsuitable storage structures (false location, insufficient shade and ventilation facilities, lack of heat insulation) - Mass reproduction of storage pests and fungi - Lack of aeration of store - High moisture content of the FFV	- Losses in weight -Losses in quality (nutritional value, germination power) -Good conditions for pest development -Condensation with subsequent development of fungi	- Protect the product from the sun / provide shade - Transport produce quickly to the packinghouse - Minimize delays before cooling - Cool the product thoroughly as soon as possible - Store the product at optimum temperature - Practice first in first out rotation - Ship to market as soon as possbile - Use refrigerated loading area - Cool truck before loading - Put insulation plastic strips inside door of reefer - Avoid delays during transport - Monitor product temperature during transport - Use the product as soon as possible
Insect Pests	- introduction of infested lots - Cross infestation from neighbouring lots or stores - Migration from waste or rubbish - Hiding places in stores (cracks, fissures) - Use of infested crates	- Losses in weight - Losses in quality (impurities such as droppings, cocoons and parts of insects, reduction of nutritional value, reduction in germination power) - increase of temperature and moisture	- Harvest at the right time - Choose tolerant varieties - Keep means of transportation clean - Remove infested cobs, panicles or pods before storage - Keep the temperature and relative humidity as low as possible (perform controlled ventilation) - Prevent any pest infiltration by sealing the store (windows, doors, ventilation facilities; e.g. with the use of insect gauze) - Repair any damage to the store immediately - Store old and new lots separately - Clean empty crates thoroughly and treat them against insects if necessary - Perform pest control treatments - Rotate stocks: 'first in - first out'
Rodents	- Penetration through badly closing doors, windows, ventilation openings, holes - Lack of barriers - Lack of hygiene in store and surrounding area (possible hiding and breeding places)	- Loss of weight - High losses in quality due to contamination of produce with faeces and urine - Contamination of produce with pathogenic agents (typhoid, rabies, hepatitis, plague, etc.)	- Prevent entry of rodents by sealing store rat-proof - Keep store and surrounding area clean - Place traps - Carry out rodent control measures

		- Damage of material and facilities (crates, doors, electric cables)	
Birds	- Open or broken doors, windows, ventilation openings or roofs	- Losses in weight - Damage to crates - Contamination of stored produce with droppings and pathogenic agents	- Bird-proof stores (carry out repair work, fit grilles or nets) - Remove any nests of granivore birds from the store and surrounding area

Annex 6: New storage options (Costa, 2014)

SMALL (<100kg) Option 1: Super Grain Bags.
Multi-layer polyethylene storage bags created a highly effective, hermetic storage environment for all crops. Water resistant and completely airtight. Placed inside ordinary storage bags for additional layer of protection.
Price: USD $2.50 – 3.00
Life: 2-3 harvests

SMALL (<100kg) Option 2: Zero Fly Bags.
Insecticide infused polypropylene bags provided a powerful killing action against insects, limiting infestation of the grain within the bag. Not hermetic. Short period where insects were able to survive before contact with inner lining of bag.
Price: USD $TBA
(estimate ≤$3.50 each)
Life: 2-3 harvests

Medium (100 - 150kg) Option 3: Plastic Silos.
Plastic PVC storage units – simple conversion of locally produced liquid storage containers. Created a highly durable storage facility and with some minor adjustments provided an effective hermetic storage environment.
Price: USD $20.00 – 36.00
Life: 5-7 Years

Med/Lge (540 – 1200+kg) Option 4: Metal Silos
Robust units constructed from galvanized iron. Outstanding storage environment for all crops. Water resistant and hermetic. Positioned correctly created an effective non-living storage environment. Long-term solution.
Medium Price: USD $200.00 – 250.00
Large Price: USD $260.00 – 320.00
Life: 20-25 Years

Large (1000+kg) Option 5: GrainSafes
Made of food-grade, UV-resistant flexible PVC. Designed for both indoor and outdoor installations. Able to store all crops for prolonged periods without risk of moisture ingress, pest infestation and fungal growth. Hermetic.
Price: USD $180.00 – 200.00
Life: T.B.A

Large (1000+kg) Option 6: Traditional Granaries.
Improvement to traditional storage. Made of local material and inexpensive to construct. Rodent protection added, but unable to resolve major post-harvest problems of pest infestation, moisture control and resistance to the elements.
Price: USD $TBA
Not hermetic.

Annex 7: **Average Recorded Losses (MAIZE) based on New Technology Farming Equipment– Uganda and Burkina Faso (Costa, 2014)**