METHOD MATTERS

Exploration and reflection on the study of farmers' demand for vegetatively propagated seed.

FLEUR KILWINGER

Propositions

1. Seed systems are diverse but the strategies scientists use to 'make' and 'remake' them are not.
   (this thesis)

2. The risk that scientific artefacts are treated as a black box increases in an interdisciplinary research setting.
   (this thesis)

3. Because of the current reward system in research, scientific publishing becomes and end in itself, rather than a means for the co-construction of knowledge.

4. Scientists turn the world into words and consequently those words are turned into worlds.

5. Things as economies, markets and money started to exist because we believe in them, now their existence defines our believes.

6. Change the way you see things, and the things you see change.

Propositions belong to the thesis entitled:
Method Matters: Exploration and reflection on the study of farmers' demand for vegetatively propagated seed

Fleur Kilwinger
Wageningen, 5th of July 2022

Method Matters

Exploration and reflection on the study of farmers' demand for vegetatively propagated seed

Fleur B.M. Kilwinger

Thesis committee

Promotor

Prof. Dr C. Leeuwis

Personal Chair Knowledge Technology and Innovation Group

Wageningen University & Research

Co-promotors

Dr C.J.M. Almekinders

Associate Professor, Knowledge Technology and Innovation Group

Wageningen University & Research

Dr Y.K. van Dam

Assistant Professor, Marketing and Consumer Behaviour Group

Wageningen University & Research

Other members

Prof. Dr E.H. Bulte, Wageningen University & Research

Dr J.A.B. Duncan, Wageningen University & Research

Dr P.R. Gildemacher, Royal Tropical Institute, Amsterdam, The Netherlands

Dr P. Rutsaert, International Maize and Wheat Improvement Center, Nairobi, Kenya

This research was conducted under the auspices of the Graduate School of Social Sciences (WASS)

Method Matters

Exploration and reflection on the study of farmers' demand for vegetatively propagated seed

Fleur B.M. Kilwinger

Thesis

submitted in fulfilment of the requirements for the degree of doctor
at Wageningen University
by the authority of the Rector Magnificus
Prof. Dr A.P.J. Mol
in the presence of the Thesis Committee appointed by the Academic Board
to be defended in public
on Tuesday 5 July 2022
at 4 p.m. in the Omnia Auditorium.

Fleur B.M. Kilwinger.

Method Matters: Exploration and reflection on the study of farmers' demand for vegetatively propagated seed

228 pages

PhD thesis, Wageningen University, Wageningen, the Netherlands (2022)
With references, with summary in English

ISBN: 978-94-6447-233-2
DOI: https://doi.org/10.18174/569974

TABLE OF CONTENTS

CHAPTER
One

General Introduction

SEEDS FOR DEVELOPMENT

Seeds are a basic element of agricultural production. Seed herein means any type of propagate, such as 'true seeds' in the botanical sense that result from generative reproduction, and any other type of vegetative propagate such as a cutting, tuber or stolon that can be used to reproduce plants. Use of 'improved seed' is considered to play an important role to increase global food security, reduce poverty, and improve livelihoods. Improved seed is generally described as via technology enhanced high yielding seed (Yapa, 1993). Technology herein means, the application of genetic principles and practices via breeding techniques - such as hybridization and biotechnology - to develop varieties (Villa et al., 2005), as well as the improvement of seed multiplication techniques that lead to improved physiological seed quality. In addition, use of improved seed is seen as a key solution to challenges such as malnutrition and climate change because breeding can result in nutritious, and resistant crop varieties. Adoption of such improved varieties by smallholder farmers is therefore a central part of many agricultural development initiatives in the global south.

Vegetatively propagated crops are important staple crops in many developing countries. Despite this importance, farmers' demand for improved 'seed' of vegetatively propagated crops remains understudied (Almekinders et al., 2019a). Vegetatively propagated crops have different characteristics than grains and pulses which so far gained most attention in research programs. One of those differences is that farmers easily can save seed from previous cropping cycles. Because of the clonal nature of these crops, multiplied material stays true to type. A drawback is that saving seed can lead to 'seed degeneration'. Seed degeneration refers to the process of accumulation of pathogens in propagation materials over successive crop cycles and is arguably one of the main causes of low productivity of e.g. potato in developing countries (Thomas-Sharma et al., 2016). To overcome seed degeneration it is therefore of high importance

in vegetatively propagated crops not only to improve the availability and accessibility of improved varieties, but also that of clean planting material of high physiological quality. The promotion of formal seed sources that could provide farmers with 'high quality seed' so far has not achieved envisioned results (Almekinders et al., 2019b; Sperling et al., 2013; Spielman and Smale, 2017), and remains a persistent item on research agendas (e.g. CtEH, 2021).

Seed systems

Farmers access seed via seed systems. A seed system is often described as a network of stakeholders involved in the production, provision, management, replacement and distribution of seed of a specific crop in a certain area (Bentley et al., 2018). The definition of a seed system used in this thesis is broader and includes the interaction between several aspects that operate in the biophysical and social sphere (figure 1).

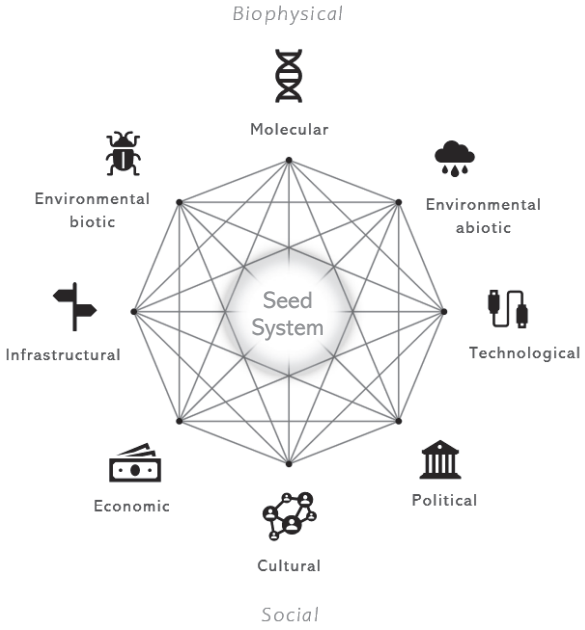


FIGURE 1. Different perspectives on seed systems that highlight several interacting aspects that influence where, when why and how seed is available and how it diffuses.

Seed systems can be approached from a molecular perspective that involves aspects such as genes, nutrients and proteins embodied in the seed or present in its surroundings. They can be approached from an environmental perspective involving biotic aspects

such as the soil microbiome, pathogens and pollinators; abiotic aspects such as water, temperature and air; and the interaction between those such as nutrient cycles and soil structure that for example influence seed germination rates. Infrastructural perspectives regard aspects such as roads and transport mechanisms through which seeds are distributed, and storage facilitates to keep seed. Technological perspectives include aspects such as sowing machines, breeding techniques, and artificial fertilizers. Economic perspectives look into aspects such as markets, business models, and subsidies and taxes for agricultural inputs and outputs. In a political perspective aspects such as seed policies, agricultural institutions and laws are taken into consideration. Cultural perspectives look into aspects like agricultural management practices, social norms, cultural values and believes, which are important to understand seed exchange and transactions between different seed system actors.

All these aspects interact and in one way or another influence where, how, why and what seed is available and diffuses. The stakeholders/actors involved in seed production, provision, management, replacement and distribution (Bentley et al., 2018) are also part of the seed system. Taking a broader perspective on seed system acknowledges that the actions of those actors are influenced by, and also influence, those different aspects. The decisions of actors in a seed system depend on the current aspects that are present, and those decisions simultaneously shape aspects in the seed system.

Seed systems are often differentiated in two parts: formal and informal (figure 2). The informal seed system, also called the local-, farmer-, or traditional seed system, refers to the activities whereby farmers themselves produce, disseminate, store and access seed (Sperling et al., 2013). Seeds can be obtained from farmers' own harvest, exchange with fellow farmers, or local markets. Informal seed systems are characterized by a high diversity of varieties, making them highly resilient in general (Barker et al., 2021; Sperling et al., 2013). Farmers are important actors in creating and maintaining this diversity (e.g. Villa et al., 2015; Brush, 1995; Longley, 2000). By repeated local production and selection, seeds get adapted to their agro-ecological and socio-economic environment in various ways. This 'manipulation' of plant populations by planting specifically selected seeds can be seen as the dawn of agriculture (Harari, 2014), and

over centuries has led to development of what are called 'landraces'. Landraces harbour important genetic diversity and have significant socioeconomic as well as heritage value (Villa et al., 2015). A drawback of informal seed systems is that the quality of seed often is variable.

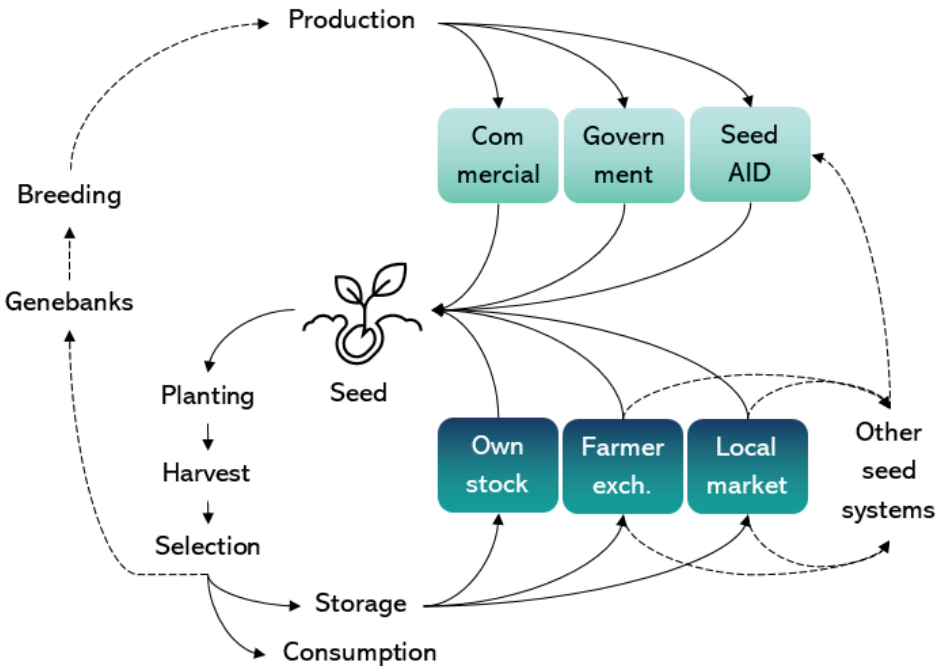


FIGURE 2. Schematic representation of a seed system. Dark cylinders represent informal sources, and light cylinders formal sources. Adapted from Scoones and Thompson, 2011 and Almekinders and Louwaars, 1999.

Formal seed systems are characterized by linearly organized production and distribution of seed. Seed of approved and registered varieties is produced under strict quality control and tested according to specified guidelines (Almekinders et al., 1994). An important aspect of formal seed systems is the development and introduction of 'improved varieties'. Farmers own selection procedures can create a high diversity of locally adapted landraces, resulting in resilient seed systems, but does so in a rather slow manner. To speed up this selection process, people have specialized in crossing plants

with beneficial traits applying genetic principles (Gepts and Hancock, 2006). This is referred to as the applied science of plant breeding which further combines knowledge of agronomy, botany, plant physiology, pathology, entomology, biochemistry and statistics (Schlegel, 2003). Breeding has significantly contributed to the increase of agricultural production, and continues to be important in a fast changing world to address existing and newly emerging challenges.

Although the distinction formal and informal seed system is often made, their boundaries are rather blurred. For example, defining what is an 'improved variety' or a 'landrace' is quite challenging as farmers could also apply genetic principles while selecting seed, or be part of a participatory plant breeding program (Almekinders 2001; Villa et al., 2005). Furthermore many interactions exist between both systems (Scoones and Thompson, 2011). For example, landraces found in the informal system, can be brought in the formal system for testing, registration, multiplication, certification and official release via formal channels. Moreover, landraces are regularly used by breeders to develop new and improved varieties. Those improved varieties might be released via formal seed channels, but can quickly be absorbed in the informal system once farmers recycle and disseminate them through farmer-to-farmer exchange (Scoones and Thompson, 2011).

There are differences among crops regarding the absorption of improved varieties in the informal system. Hybrid seeds of generatively propagated crops lose their heterosis effect and uniformity already in the first generation when seed is multiplied. This provides some guarantee that farmers make seasonal purchases in order to maintain similar genetic properties, also referred to as economic sterility (Kloppenburg, 1988). Open pollinated crops and vegetatively propagated crops in contrast largely maintain their genetic properties when multiplied by farmers. As a consequence, the potential economic returns on these crops for breeders are lower which is one of the reasons why they are less attractive for private sector investment. This further provides an example of how aspects in the biophysical and social sphere in seed systems interact and influence each other.

Seed system interventions

In developing countries, seed supply is dominated by informal systems (McGuire and Sperling, 2016), including the 'seed' supply of vegetatively propagated crops (McEwan et al., 2021). The majority of farmers grow farm-saved seed of landraces or improved varieties. When farmers grow improved varieties or seeds obtained from formal sources, they usually access those via seed aid programs or other seed system interventions. Seed system interventions are part of many agricultural and rural development programs and aim to increase the availability of-, improve access to-, and expand use of-, improved seed among farmers. Projects of different shapes and scales therewith aim to improve seed security, agricultural production, food and nutritional security, and reduce poverty. There is, however, a general notion that despite the tremendous investments, the outcomes of these interventions often have not met expectations and left the interests of many farmers still unattended (Almekinders et al., 2019a). Seed system interventions usually involve strengthening of the formal seed system by supporting and encouraging farmers to adopt improved varieties from formal seed sources (McEwan et al., 2021). Adoption studies therefore make important contributions to improve the design and functionality of future seed system interventions.

The common theoretical perspective on adoption of innovations

There is extensive scholarship seeking to explain the adoption of agricultural innovations, much of which draws on Rogers 'diffusion of innovations theory' (1962). This theory mainly regards adoption as an individual, linear, process that is determined by multiple variables of the individual's identity and perception of the situation. In the process of adoption, or rejection, of an innovation is an individual goes through several stages in which information provides a key role (Leeuwis and Aarts, 2021). Those stages can be roughly divided into awareness, interest, evaluation, trial, and adoption. New theories and models have evolved from this theory, but most of these have one thing in common: they include numerous variables or 'determinants' that are expected to predict an individual's decision to adopt. Those determinants regard demographic characteristics such as age, gender and education, personality traits like risk behaviour and innovativeness, and social influences such as values and believes.

Using the diffusion of innovations and related theories, many case studies researching the adoption of improved planting material follow a quantitative research approach with a positivist position. Commonly, adoption studies involve data collection on numerous variables via a large-N household survey which is analysed using regressions and other econometric models. The rather disappointing adoption rates of improved seed among smallholder farmers requests for more research, which tends to result in 'more of the same': more data collection via household surveys, inclusion of more possible determinants (variables), and improvement of statistical models. The selection of these variables is usually based on earlier research, not necessarily conducted in the same context (e.g. Doss, 2006; Knowler and Badshaw, 2007; Pannell et al., 2006). This has led to an extensive list of possible determinants, which has even made one author of a review on adoption literature to state that: "*It seems that in the empirical literature every measurable characteristic of farms and farmers has been found to be statistically related to some measure of adoption of some innovation*" (Pannell et al., 2006).

Novel theoretical perspectives to understand adoption

The diffusion of innovations theory has made significant contributions to the understanding of adoption. Nevertheless, instead of doing 'more of the same' research some scholars are critical about the theory and have pointed out its limitations. A main criticism is oversimplification of technology as an universal package which can be replaced by newer and better ones (e.g. Glover et al., 2019, Sartas et al, 2020; Wigboldus et al., 2016). It is argued that the diffusion of innovation theory is especially inadequate for complex technologies which involve the integration and coordination of multiple social and technical components (Glover et al., 2019).

Using improved seed can be regarded as such, considering the different interacting aspects in both the biophysical and social sphere that define seed systems. Growing improved seed usually does not mean the farmer just grows a seed with different genetic properties. It might require growing a different type of propagate (for example tissue-culture material), that requires different management practices (such as different or more inputs); often different replacement dynamics are advocated (higher variety turnover and more frequent seed replacement); and different ways of acquisition of the material

are promoted (from informal networks to formal sources) or even are necessary when seeds are economically sterile. This in turn requires access to credit, markets and specific knowledge. Thus, addressing for example a phytosanitary problem not only requires changes in the biophysical sphere such as growing a resistant variety, but simultaneously implies many changes in the social sphere.

To better understand adoption, diffusion/scaling of innovations, or technological change[1] of such complex technologies and innovations, new theoretical perspectives and frameworks have been developed such as the Propositions, Encounters, Dispositions and Responses (PEDR) framework (Glover et al., 2019), the scaling-readiness approach (Sartas et al., 2020), and the theory of jobs to be done (JTBD; Christensen et al., 2016). The PEDR framework emphasises the agency of people involved in the process of technological change that is based on the perceived opportunity to put and object or material to use. This is called the affordance of an object (Gibson, 2014). This perception is subjective, situational and relational: it depends on the properties of the material, object or environment and the characteristics of the people interacting with it. This includes their capacities, resources and social and cultural norms (Arora and Glover, 2017). A key insight to draw form this theory is that the affordance of different agricultural technologies is specific to people and situations (Glover et al., 2019).

Likewise to the PEDR framework, the scaling-readiness approach views technologies and innovations as a package and embeds differences in spatial and temporal context. The main focus of the approach is on the identification of different parts of an innovation package that simultaneously need to go to scale (Sartas et al., 2020). It embodies interdependencies of interactions in stakeholder-networks. Such interdependencies are the behaviour of other actors in the value chain (vertical interdependency), the behaviour of similar actors in the value chain (horizontal interdependency), the acceptance and/or implementation of complementary behaviour by the individual (intra-individual interdependency), and past and anticipated adoption decisions (temporal

[1] In this chapter the term adoption is used to describe 'the spread of something that is considered to be desirable across a greater number of users, or across a larger geographic area, to achieve some kind of societal impact' (Leeuwis and Aarts, 2021). Other literature uses terms such as 'diffusion of innovations', 'scaling of innovations' and 'technological change' to describe this process in their theoretical perspectives.

interdependency) (Leeuwis and Aarts, 2021). Where the PEDR framework includes a main focus on differences among users, the scaling-readiness approach in contrast does not (yet) include differentiation of the potential users, but rather focusses on interdependencies and differences in the context - such as existing networks and the political and institutional environment - users are situated in.

The JTBD theory focuses on understanding what drives the choice of a specific end-user. The theory results from the observation that although the quantity of available data is larger than ever, many innovation initiatives fail. Christensen et al., (2016) argue that marketeers and product developers focus too much on correlations in unearthed data, and thereby overlook what customers are actually trying to achieve in a particular circumstance. This theory assumes that decisions do not depend on loads of characteristics that can be measured. At the theories core is the principle that users do not purchase goods or services, but bring things into their lives that get a specific job done or achieve progress towards a goal (Christensen et al., 2016; Campos, 2021). The aim is to find this causal driver behind adoption.

In the descriptions of all these theories is pointed out that new methods are needed that take different variables into consideration and are capable of measuring those. Concepts such as interdependencies, capacity for collective action, perceptions, trust, 'the consumers pain', and their interaction, are difficult or impossible to capture via survey research. For example, finding a specific driver that motivates adoption requires immersing in users lives to understand their needs, pains and aspirations which is not likely achieved via the analysis of structured survey questions (Campos, 2021). On the other hand, when only looking at the individual level important interdependencies could be overlooked: people might be motivated to change but there can be certain barriers that need to be understood.

Research methods supporting novel theoretical perspectives

Supporting such new theoretical perspectives on adoption requires methods that are capable of capturing new aspects they include. Currently, a household survey is the most common research method to understand farmers' adoption and demand of (vegetative propagated) planting material (Pircher and Almekinders, 2021; Walker and Alwang,

2015). The metrics generated with such quantitative methods like scales, trends, and patterns are often sought by actors such as designers of seed system interventions and policymakers to enable informed decisions (Almekinders et al., 2019b; Nyanga, 2012). Yet, they might not sufficiently capture specific contexts to allow generalization and lack explanatory power. This context could be provided by additional qualitative, in depth research. However, also qualitative research methods receive criticism, mainly due to the absence of standardized means to assure validity and proneness to bias (Maxwell, 2004; Stone and Flachs, 2014). It has even been argued that in some cases 'supplied qualitative stories' are specifically selected testimonies of farmers used in an effort to de-bunk (quantitative) scientific analysis (Giller et al., 2017; Krupnik et al., 2019). This provides a justification to have a close look at the research methods used and the outcomes and findings they produce.

Standardized research methods - such as surveys - can be extremely good at what they do, when they are applied in the right research context (Law, 2004; Doss, 2006). Survey research has significantly contributed to our understanding of important causal relations such as poor health and social inequalities and the prevalence of night blindness due to vitamin-A deficiency and geographic location (Darmon and Drewnowski, 2008; WHO, 2009). Such studies have been the basis for major health, food and educational campaigns (Law, 2004). Thus, the problem does not seem to be with the methods themselves, but rather their application to unsuitable research questions and contexts (Law, 2004; Doss, 2006). Surveys might be inappropriate to measure the irregular, transitory, complex or messy (Law, 2004). Possibly, this is exactly what seed systems are seeing the interaction of many aspects in the biophysical and social sphere. Our research methods so far seem only capable of capturing a biased or blurry snap-shot of a specific part of the seed system. This could be avoided by a more holistic methodological approach that seeks the combination of different perspectives via transdisciplinary and interdisciplinary work (Almekinders et al., 2019b).

An interdisciplinary toolbox for seed systems of vegetatively propagated crops

Many studies and research programs are established to understand farmers' adoption of improved seed and use of formal seed sources (e.g. Walker and Alwang, 2015; Thiele

et al., 2021). The CGIARs Research Program on Roots, Tubers and Bananas (CRP-RTB) is one of the large-scale research programs that aims to enhance the use of high quality planting material of vegetatively propagated crops among smallholder farmers in developing countries (Roots, Tubers and Bananas, 2020). Acknowledging that understanding seed systems - and the decisions that farmers and other stakeholders within them make - requires an interdisciplinary approach, a 'toolbox' for studying seed systems was developed as part of the program (Andrade-Piedra et al., 2020).

This toolbox includes methods from several scientific disciplines to understand farmers' seed-sourcing practices. Farmers' seed-sourcing practices regard their decision making towards varieties, seed quantities, replacement dynamics and seed sources. Some of the methods in the toolbox can be regarded as 'conventional' as they are regularly used in adoption studies. The toolbox also includes methods that originate from other scientific disciplines. These could be considered as 'novel' tools in the area of seed systems research. Examples of such methods are choice games, means-end chain analysis and willingness-to-pay studies which have their roots in economics, marketing and consumer studies. These 'novel' research methods might better fit novel theories to understand adoption. For example, the means-end chain analysis is based on the personal construct theory (Kelly, 1955; Reynolds and Gutman, 1988). Both embedded in a pragmatic and functionalist approach, the personal construct theory has a strong parallel with the theory of affordance on which the PEDR framework developed by Glover et al. (2019) is based.

Despite the potential benefits of this broad range of tools from different disciplines, they have to be adapted to the context. First, the characteristics of vegetatively propagated crops differ from those of true seed staple crops -such as grains an pulses- that used to dominate the research and development agenda (Andrade-Piedra et al., 2016). For example, breeding is more complicated due to complex genetics, seed is more bulky and perishable, reproduction rates are relatively low, and subsequent cycles of multiplication can lead to seed degeneration (McEwan et al., 2021). Research methods, even 'conventional' ones, have to be adapted to suit these characteristics. Second, before applying 'novel' methods from other disciplines their underlying assumptions should be

explored and considered if those are valid when applied in a new context. For example, observations from the field of consumers studies revealed that different methods to assess willingness-to-pay might not be similarly functional for all product categories (Breidert et al., 2006; Grunert et al., 2009), and when simply copying willingness-to-pay methods to understand rural-African consumers theoretical and practical ramifications might emerge (Morawetz et al., 2011).

Different tribes of scientists and their worldviews

Interdisciplinary research using a broad range of methods that are capable to capture the many interacting aspects playing a role in seed systems requires collaboration of wat Latour and Woolgar (1986) call different tribes of scientists. They use the word 'tribe' to emphasize that scientists from different disciplines (and sometimes even within the same discipline) have their own set of beliefs and practices. Therefore, when combining and applying new theoretical perspectives that broaden the methodological framework, contrasting perspectives might emerge (Kanbur and Shaffer, 2007). Nevertheless, interdisciplinary research and holistic methodological approaches are considered essential to tackle problems regarding humans and their interaction with the environment (Tobi and Kampen, 2018). To make this happen, scientist of different disciplines thus need to understand and accept each other's 'culture' and worldviews.

Those worldviews can be captured and distinguished by ontology and epistemology. In science, ontology refers to believes about the nature of reality (what is real or true), and epistemology refers to the nature of knowledge (how can be known what is real or true). This has resulted in an extended list of '-isms' (objectivism, constructivism, positivism, realism, pragmatism, etc.) that each take a different perspective on reality and knowledge. To discuss this extensive list of -isms is beyond the scope of this thesis, but we focus on two dominant worldviews that could be regarded as the edges of the spectrum of -isms.

One worldview takes the assumption that there is a one world, a single reality, which is independent of humans' experiences (Jonassen, 1991). This reality can be objectively discovered, therewith finding what is truth. Knowledge can and must be developed objectively, without influence of researchers and participants values. When

appropriately developed, knowledge is truth, meaning it is certain, accurate and coherent with reality (Park et al., 2020). The other worldview takes the assumption that reality is subjectively created. This does not mean that the existence of an external reality is denied, but rather that each of us constructs their own reality through interpretation of perceptual experiences of this external world (Jonassen, 1991). How one constructs knowledge is a function of the prior experiences, mental structures, and beliefs that one uses to interpret objects and events.

When studying something as complex as seed systems, which regard the interaction of aspects in the biophysical and social sphere, diverse epistemologies are needed. As an illustration for these different world views, and how they can be applicable to study a single object, we can use a plant. There is a common statement that says: 'there is no such thing as a weed, only plants growing in inconvenient places'. What is an inconvenient place for a plant to grow, is subjective. Similarly, it can be stated that there are no resources, resources 'become' at the moment value can be created from them (De Gregori, 1987; Zimmermann, 1933). Thus, there might be a single reality out there which includes the existence of a plant, but this plant can be regarded either as an inconvenience (then we call it a weed), a resource (then we call it a crop), or anything else based on its subjective value. The construction and transformation of 'things' into something valuable, worthless or even problematic is largely determined by societies norms and values, science, and technology.

Research methods as the object of study

Acknowledging such different worldviews makes us further reflect on what research methods exactly are and do. One view of method is that reality has a definite form that is independent of the methods used to study it, and that the job of methods is to discover and describe this reality as best may be (Law, 2009). The social life of methods contests that research methods are merely tools to learn about the world which has definite features that can be reported and turned into data. According to Law et al. (2011), methods have a double social life. Methods are social because they are constituted by the social world, are created with a purpose, and reflect on the concern of their advocates. They are also social because they help constitute and organize the world. In

other words, they are performative. Taking the perspective that truths are not universal does not deny that the world is solid, regular and largely independent of what we think of it, but uses the idea that methods are practices that tend to enact realities as well as describing them and treats them as performative. In other words, the real is realized within a network of practices that enact and perform it (Law and Mol, 2001). Research methods capture a specific part of reality in a particular way, while it remains unknown what part of reality might escape. In this way certain parts of reality are performed, whereas others are not, meaning that some realities are brought into being, while shutting down others (Law et al., 2011).

The first social life of methods implies that methods are developed, selected and applied with a purpose. The development and/or application of other research methods thus likely results from a shift in the interest, problems or purposes of the social, and might enact a different social. The call for Africa's Green Revolution and 'the neoliberal agenda' have significantly changed research (and donors) emphasis of agronomy towards the industrialization and commercialization of agriculture (Andersson and Sumberg, 2017; Scoones and Thompson, 2011;). 'Marked-led technology adoption' and 'public-private partnerships' have a significant place in current projects and visions around agricultural innovation (e.g. CtEH, 2021; CIP, 2021 AGRA, 2022). With these interests, and the underlying theory that the impact of improved seed is highest when embedded in the market, research methods from the realm of economics, marketing and consumer behavior are welcomed to the arena.

The second social life of methods implies that research methods do not simply describe a part of a reality, but also contribute to creating the realities those representations depict (Law et al., 2011). In the case of research methods to understand famers' seed demand that means that they shape future seed availability and the associated conditions (Almekinders et al., 2019b). This is of concern to organisations, such as the Alliance for Food Sovereignty in Africa (AFSA), Southern African Faith Communities' Environment Institute (SAFCEI) and Oxfam Novib, who are critical on the dominant focus of industrialisation and commercialisation in agricultural research for development. In

open letters, they have requested donors to shift their attention to agroecology and low-input systems (ASFA; 2021; SAFCEI, 2021; Oxfam Novib, 2021).

The concerns of these agencies do not only regard the realities that are performed (e.g. considering farmers to be clients instead of partners, or the promotion of a model of industrial monoculture farming), but as much consider the loss of those who are not performed (ASFA; 2021; SAFCEI, 2021; Oxfam Novib, 2021). Examples are a loss of culture and diversification, a loss of biodiversity and genetic erosion, and the loss of indigenous knowledge and the deskilling of farmers (e.g. Villa et al., 2005; Fitzgerald, 1993; Nazarea, 2006). And those concerns even regard the potential loss of realities that we are aware of, let alone what realities might go undetected (and unenacted) by our research methods that we are not aware of. Taking this perspective on method, it asks us to explore what it is that our methods actually do, and then whether or not this is desirable (Law, 2004). Research methods can only reveal a specific part of the image. Therefore changing research methods does not merely change what is 'discovered' or what we shed light on, they also exclude different parts of the image that are left in the dark.

SCOPE OF THIS STUDY

In this introduction I have provided a short overview of seed systems, seed system interventions, adoption studies and research methods. Seed systems are complex and involve the interaction of many aspects in the biophysical and social sphere. Seed-system interventions are often made often made to improve availability and accessibility of improved seed for farmers in developing countries. Adoption rates of improved seed are still considered too low despite the many efforts. Therefore many adoption studies are conducted that can improve the design of future seed system interventions. Nevertheless, it is argued that the most dominantly used theory on the adoption might too simplistic to understand farmers' decision-making in complex setting such as seed systems. New theoretical perspectives on adoption have been proposed that require different research methods that can capture parts of the complexity that might escape from the picture when applying conventional household surveys.

The RTB project has developed a toolbox including research methods from different scientific disciplines. Interdisciplinary research can address the complexity of seed systems and create a more holistic image. *The first focus of this thesis* will therefore be on the outcomes and insights obtained with different tools from the RTB toolbox that aim to understand farmers' seed-sourcing practices. This regards their variety preferences, required seed quantities, seed replacement dynamics, and preferred seed sources, i.e. their demand for seed. To make interdisciplinary research successful, it requires scientists from different 'tribes' who have different worldviews to collaborate. When we consider the different worldviews of scientists, the perspective on methods themselves also changes. *The second focus of this thesis* is on method itself by taking them as the objective of study. Underlying assumptions of methods are explored as well as their validity in the context of smallholder farmers' seed-sourcing practices for vegetatively propagated crops. Using case studies from the RTB research program, I will illustrate how different methods capture specific aspects of farmers' seed-sourcing practices and how other aspects might be ignored.

Objectives of the study

The overarching objective of the thesis is to apply and evaluate research methods used to understand smallholder farmers' seed-sourcing practices for vegetative propagated crops in Eastern-Africa. The selection of methods is based on the toolbox developed by the CGIAR's Research Program on Roots, Tubers and Bananas (CRP-RTB). This toolbox contains collection of research methods which can be used to understand seed systems of vegetative propagated crops. The selected methods from the toolbox that contribute to understanding farmers' seed-sourcing practices are presented in figure 3 (number 5-9) and include:

1) Large-N household surveys (in combination with: No 5. Seed tracing)
2) In-depth interviews (No 6. Small-N exploratory case study)
3) Focus group discussions (No 7. Four-square method)
4) Means-end chain analysis (No.8 Means-end chains)
5) Willingness-to-pay studies (No. 9 Experimental auctions).

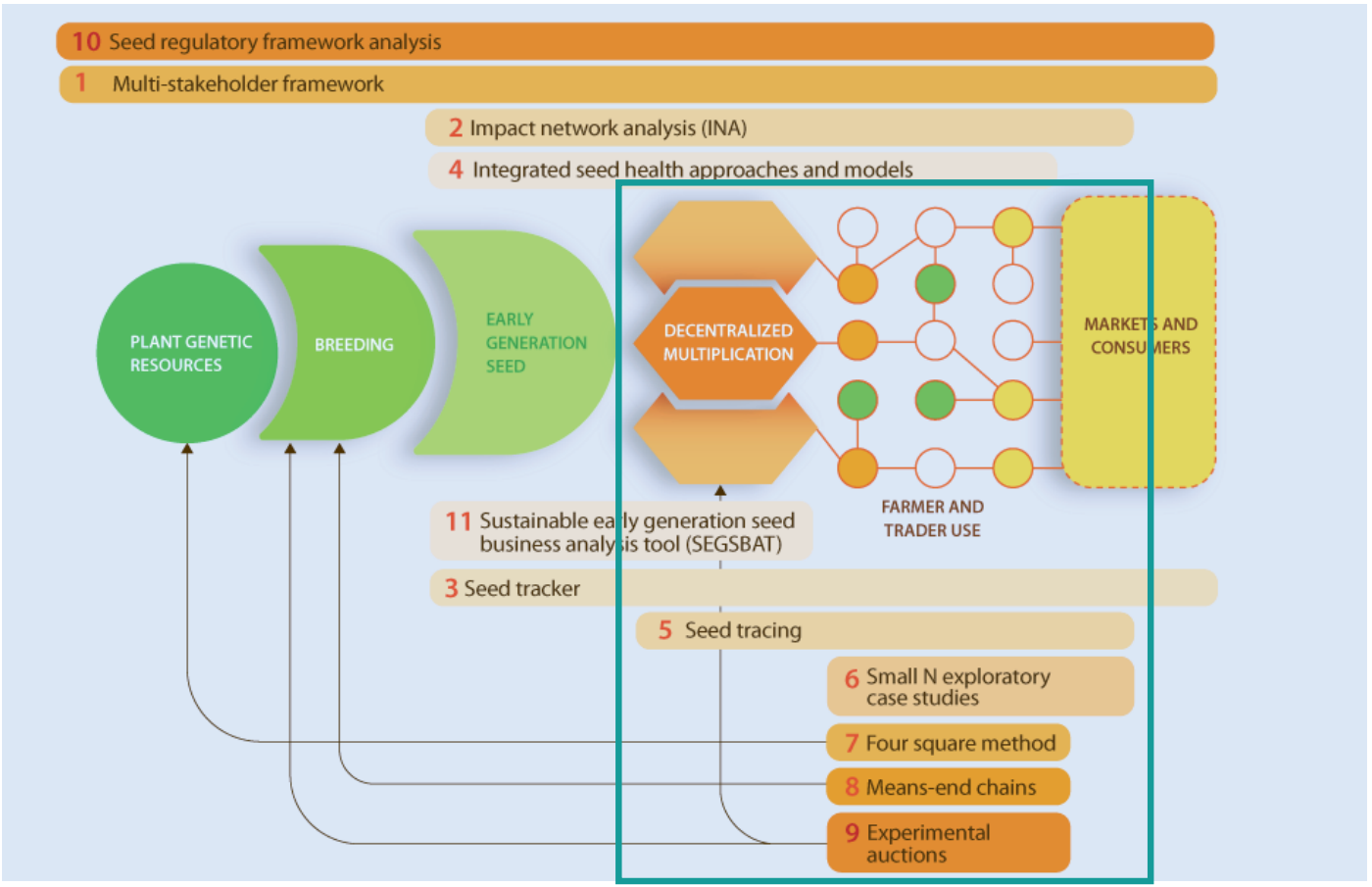


FIGURE 3. Schematic image of the seed value chain and the areas of the value chain which are addressed by the research tools included in the RTB toolbox. The tools providing insight in farmers' seed-sourcing practices are: 5) seed tracing; 6) small N exploratory case studies; 7) Four square method; 8) Means-end chains; and 9) Experimental auctions.

The selected tools include qualitative and quantitative methods. Some tools can be regarded as 'conventional' in their application in seed system research, such as surveys. Others can be regarded as 'novel' in their application in seed system research as they result from other research fields, such as experimental auctions and means-end chain analysis (figure 4).

FIGURE 4. Six research tools selected from the RTB toolbox to understand farmers' seed sourcing practices. The tools are classified based on methodology (quantitative and quantitative) and frequency of application to study seed systems (conventional and novel). The classification for frequency of application is based on a systemic review paper that identified methods used to understand farmers' demand for seed of root, tuber and banana crops (Pircher and Almekinders, 2021).

To address the overarching objective of this study, four underlying objectives are addressed:

- Objective 1: To describe the insights into farmers' seed-sourcing practices that are provided by different research methods (Chapters 2, 3, and 4)
- Objective 2: To explore how research methods can be improved and better adapted to understand farmers' seed-sourcing practices (Chapters 5 and 6)
- Objective 3: To explore how the research methods used create different presences and absences and complement a more holistic understanding of farmers' seed-sourcing practices (Chapter 7)
- Objective 4: To explore how the research methods used contribute not only to describing but also to shaping farmers' seed-sourcing practices (Chapter 7).

The chapters of this thesis separately explore a research method applied to a specific case study. The case studies in which these methods were applied were part of ongoing research projects within the RTB research program in Eastern-Africa. The specific research questions addressed in the case studies are therefore the actual research questions from these projects. Although all those projects related to farmers' seed sourcing practices, the papers thus address a slightly different research question. Of the applied methods, empirical findings will be discussed. In addition it is explored how research methods can be adapted to improve their validity in the specific research context. Via a literature review, the key assumptions of the evaluated research methods are elicited and discussed. Thereafter is explored whether it is plausible that these assumptions hold. The first three chapters focus on outcomes generated with the tools whereas the last two chapters focus on methodology. The discussion chapter will link the knowledge described in the independent chapters and discuss the methods in the light of the social life of methods.

Thesis outline

In chapter 2 the outcomes of a large-N household survey, applied to understand seed sourcing practices of cassava farmers in Rwanda, are described (figure 5). Large-N household surveys are the most dominant research tools to understand adoption of agricultural innovations. In this study, survey data is used to generate farmer typologies

that are linked to a seed tracing study. The outcomes of the survey data and seed tracing are discussed to support the development of tailored seed business models.

Chapter 3 describes the seed sourcing practices of banana farmers in Central Uganda based on a small-N case study. Two methods, focus group discussions and in-depth interview are applied with a specific focus on the value and uses of different banana varieties and farmers' evaluation of seed quality. It relates cultural aspects of banana management and what implications those management practices have for seed system interventions. Qualitative case studies are often recommended as a complementary research method to surveys to increase their sensitivity to context.

Chapter 4 describes the results of a means-end chain analysis applied to understand Ugandan banana farmers preferences towards different seed sources. The means-end chain analysis is a relatively new method in this particular research area and has its roots in marketing research. One characteristic of the means-end chain analysis is that qualitative data is transformed into quantitative data. Other benefits are that participants are allowed to select and verbalise the attributes they use to evaluate a product or service. The underlying theory of means-end chain analysis has considerable overlap with the theory of affordance on which new theoretical perspectives on adoption of agricultural innovations are based.

Chapter 5 and 6 are methodological contributions. In the chapters is discussed how 'novel' methods, experimental auctions and the means-end chain analysis, can be improved and adapted to increase validity in the specific research context. The underlying assumptions of the method have been explored via a literature study. Based on empirical findings is discussed why certain assumptions might be violated and what the implications of such violations are on the results.

The final chapter forms an overall discussion. It provides an overview of the insights on farmers' seed sourcing practices that are provided by the applied research methods. In other words, what presences and absences the methods generate. Further is discussed how methods can complement each other for a more holistic understanding of seed systems. Finally, the performative nature of research methods in seed system research is discussed using the social life of methods.

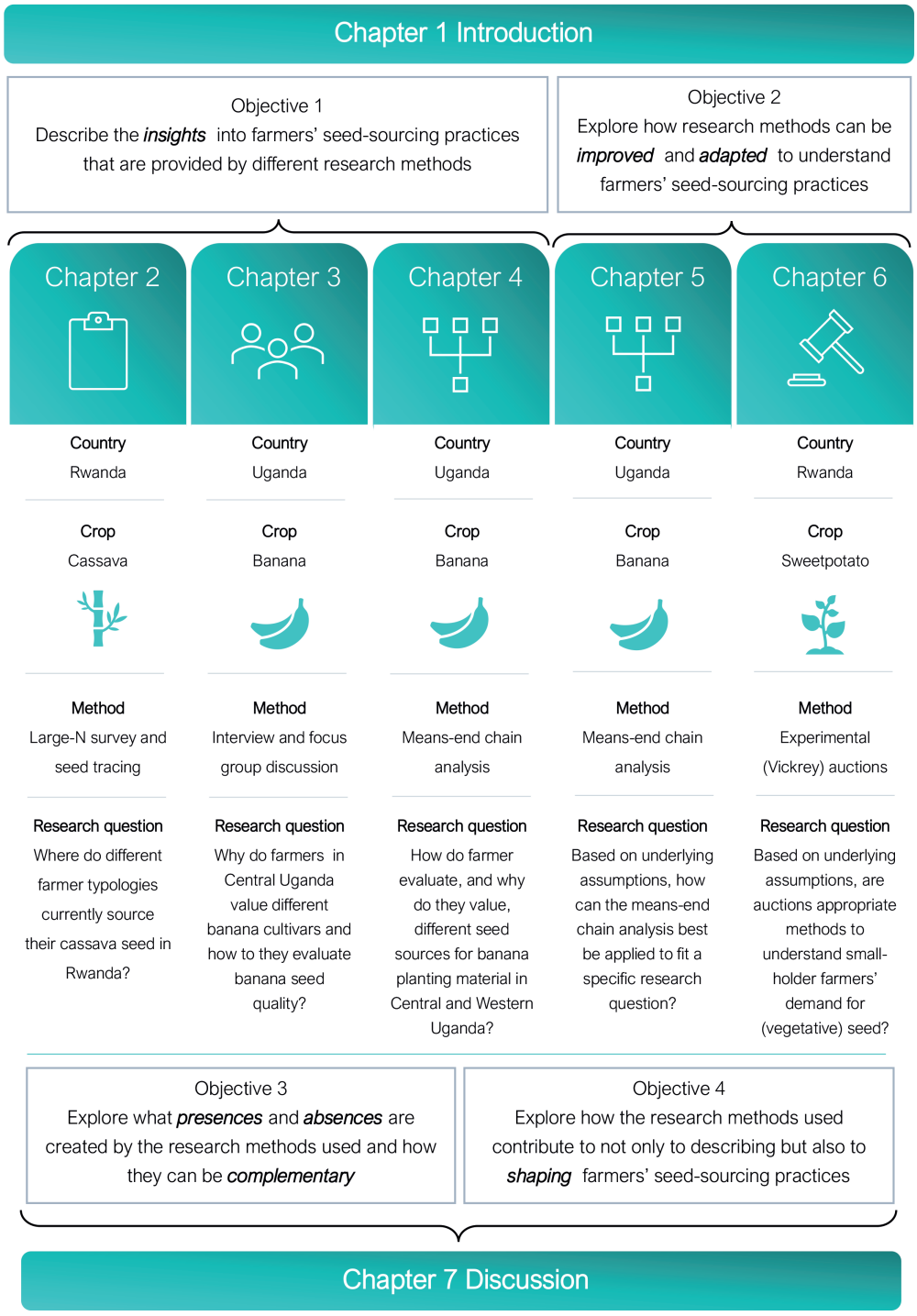


FIGURE 5. Overview of the thesis outline.

CHAPTER
Two

Characterizing cassava farmer typologies and their seed sourcing practices to explore opportunities for economically sustainable seed business models in Rwanda

Publication information

Adapted version of: Kilwinger F, Mugambi S, Manners R, Schut M, Tumwegamire S, Nduwumuremyi A, Bambara S, Paauwe M, and Almekinders C. (2021). Characterizing cassava farmer typologies and their seed sourcing practices to explore opportunities for economically sustainable seed business models in Rwanda. Outlook on Agriculture, 50(4), 441-454.

ABSTRACT

The overdependency on local cassava varieties and informal seed sources by farmers in Rwanda has contributed to the spread of cassava viral diseases. The use of improved planting materials made available through formal seed sources, that assure seed quality, is one way to prevent future disease outbreaks. In order to increase the availability of, and farmers access to, such materials there is increasing interest to develop seed business models. This study aims to understand seed sourcing practices of different farm typologies to inform the development of tailored seed business models. A total of 390 farmers were interviewed and the collected data was analyzed into clusters, resulting in seven farm typologies. Seed sourcing strategies, seed replacement dynamics and purchasing behavior of these typologies were explored via a seed tracing study. We find that more commercial oriented farmers have better access to formal seed sources. Nevertheless, the majority of farmers in all typologies accessed new varieties and quality cassava seed via informal channels. At both formal and informal sources, cash investments in seed were mainly made by the categories of better-off farmers, and were onetime investments to acquire a new variety. Based on farmers current seed sourcing practices, clarifications on the differences between farmers and their willingness-to-pay, the roles of seed degeneration, cost-benefit analysis, value propositions and profit formulas seem important requirements for the further development of viable cassava seed business models. We conclude that tailoring seed business models can have a high potential as it acknowledges differences among farmers, but that careful coordination is needed to ensure that one approach or intervention does not contrast with and/or undermine the others.

INTRODUCTION

Cassava production and its challenges in Rwanda

Cassava (*Manihot esculenta*) is a major staple crop in sub-Saharan Africa with over 200 million people depending on it for a large part of their calory intake (Manyong et al., 2000). The crop is gaining further economic importance as a raw material for the industrial processing of foods, ethanol, and starch. Cassava Mosaic Disease (CMD) and Cassava Brown Streak Disease (CBSD) are currently the most threatening biotic stresses to cassava production in East and Central Africa (Alicai et al., 2007, Legg et al., 2001, Tumwegamire et al., 2019). The two diseases cause devastating effects on root quantity and quality, with field and storage losses ranging from 30% to 100% (Patil et al., 2015; Kawuki et al., 2016; Okonya et al., 2019). Both diseases spread via a whitefly vector (*Bemisia tabaci*) and the use and exchange of infected planting material[2] (Legg et al., 2011). This means that farmers' use of local susceptible varieties and recycling of stem cuttings from the previous crop can aggravate the impact of the diseases. To prevent this, the introduction of resistant varieties and availability of clean planting material is of high importance (Night et al., 2011).

CBSD incidence peaked in Rwanda between 2010 and 2015, and severely threatened food security. To cope with the situation, the government of Rwanda imported clean planting materials (stem cuttings) of CBSD resistant varieties from Uganda for distribution to smallholder farmers. Cassava variety development and production of quality clean planting material in Rwanda is, like in many developing countries and for other vegetatively propagated (staple food) crops (VPCs), mainly in the hands the government and development organisations. Also typical for VPCs in developing countries, governments and non-governmental organisations (NGO) often subsidize multiplication and buy the planting material to distribute among farmers (Bentley et al., 2018; Tripp and Rohrbach, 2001; Rachkara et al., 2017).

[2] Cassava is a vegetative propagated crop. Hence cassava planting material is not 'true seed' in botanical terms. In Rwanda cassava is mainly multiplied via propagates called 'stakes'. These are stem cuttings that develop into new plants when planted. Here we use the terms seed, planting material, and stems interchangeably.

Studies that critically looked at such funding-driven strategies have observed negative consequences (Sperling et al., 2008; McGuire and Sperling et al., 2008). For example, in the short-term farmers may waste scarce resources like land and labour when provided with maladapted varieties. In the long-term, having continuous access to free or subsidized seed supply may easily create dependency among farmers and disrupt the market for seed, hindering the emergence of viable commercial seed enterprises (Tripp and Rohrbach, 2001; Rohrbach et al., 2005). Consequently, seed system research in Sub-Saharan Africa is increasingly focussed on developing economically sustainable seed business models that can carry forward the supply of improved healthy planting materials after such an intervention (Donovan et al., 2021; Sperling et al., 2013; Rachkara et al., 2017).

Seed business models

A business model can be defined as a representation of how an organization views, creates, distributes, and captures value for itself (via a profit formula), and for users (defining the value proposition). This aspect is often neglected in innovation efforts, which instead tend to focus on the goods or services themselves, rather than on management and the creation of value (Campos, 2021). Although business models are often associated with profit making, this is not necessarily true. It can be argued that non-profit organizations, including those focusing on agricultural development, already run a busines as they are under pressure to innovate to meet the continually evolving needs of their beneficiaries (Campos, 2021).

Nevertheless, moving from aid-based systems towards commercialized seed systems is considered by many as a more effective and economically sustainable (CtEH, 2021; Rachkara et al., 2017; Tripp, 2003). ‘Commercialized’ refers to activities, like buying and selling seed/planting material, with the intend of making a profit. Such commercialized seed systems can involve multiple actors like decentralized seed multipliers, seed companies, agrodealers and traders (Sperling et al., 2013). Proposed benefits of commercialized seed systems are improved access to quality seed and high yielding varieties with high market values, higher varietal turnover, increased productivity and food security, reduction of poverty and food imports, increased returns

of investments in crop improvement research, and attraction of private sector investments (Barker et al., 2021; CtEH, 2021; Maredia et al., 2019).

Private sector investments for the improvement of cassava in Rwanda has so far been low. There are many reasons why VPC seed systems are generally less attractive to commercialize by private organizations than 'true seed' crops: their genetic complexity often complicates breeding, the propagation material of VPCs is usually bulky, perishable, and easily carries pests and diseases (Bentley et al., 2018; McGuire and Sperling, 2016; Thiele, 1999), and because of the clonal nature, planting material remains 'true to type' after multiplication, providing a low incentive for farmers to become frequent buyers (Almekinders et al., 2019a).

When developing economically viable seed business models, a solution needs to be found for the challenges and bottlenecks that are related to these characteristics. Because the material remains true to type (lack of a clear value proposition), there is no incentive to invest (distorting the profit formula) in new planting material, unless the materials provided by the seed business offer a clear advantage over farm-saved seed. According to Tripp (2003), this advantage can be in the form of access to new varieties or clean seed and should translate into increased productivity benefits. This also implies that information on demand for different varieties/planting materials is available (Barker et al., 2021). Better insights into demand, farmers' seed sourcing strategies, replacement dynamics, purchasing behavior, and the underlying motivations and differences among farmers in these issues, are required.

Understanding and predicting demand

Earlier research has shown that access to, and demand for, planting material varies among farmers, even within informal seed systems (e.g. Coomes et al., 2015; Kilwinger et al., 2020b; McGuire, 2008). Furthermore, a fluctuating pattern can be observed with the demand being low after a 'good' season and high after a 'bad' season that seed businesses would have to deal with (Almekinders et al., 2019a). Several case studies have shown that farmers are willing-to-pay for VPC planting material in Sub-Saharan Africa (e.g. Bartle and Maredia, 2019; Boadu et al., 2019; Maggidi, 2019) and that commercial seed sectors are emerging in Sub-Saharan Africa (e.g. Bentley et al., 2020;

Gibson et al., 2009; Namanda et al., 2011), though there is little detail of the type of farmer who is prepared to pay and under which conditions (Rachkara et al., 2017).

The heterogeneity among farmers, their farms, and farming practices creates the risk that a "one-size-fits-all" strategy or model would favor and appeal to only a specific group of farmers. One-size-fit-all strategies might be easier to scale, but may be inefficient to achieve adoption at scale compared to more nuanced 'tailored approaches'. Those are data-driven approaches that incorporate farmers' diversity in scaling strategies, can result in higher adoption rates by meeting farmers' diverse needs and capacities, and support greater development impact and (Hammond et al., 2020).

The objective of this study is to develop farmer typologies and get insights in their cassava seed sourcing practices, seed replacement dynamics and purchasing behavior. This was done by linking farmer typologies to a seed tracing study. The outcomes can support the development of tailored seed business models. Furthermore has it been demonstrated it is important to understand social and cultural aspects that shape seed exchange as they influence disease spread and populations (Delêtre et al., 2021; Garrett, 2021). Next to a contribution to the development of tailored business models for cassava seed, the study is a methodological contribution by linking farmer typologies (Hammond et al., 2020) with seed tracing. Lessons learned from the Rwanda case study can inform the use of this approach in other countries and for other innovations.

METHODS

Study design

We used a household survey and a seed tracing study to characterize the cassava seed system in Rwanda. The household survey was conducted to cluster cassava farmers into different typologies. For the household survey we used an adaptation of the Rural Household Multi-Indicator Survey (RHoMIS) tool (Hammond et al., 2017). A sub-sample of farmers from the household survey was selected for a seed tracing study. Data from the seed tracing was then linked to the household survey data to identify patterns of seed movement among different stakeholders and farmer types.

Site selection and sampling

For the household survey we used an adaptation of the Rural Household Multi-Indicator Survey (RHoMIS) tool (Hammond et al., 2017). The RHoMIS tool is designed to rapidly characterize a series of standardized indicators that cover the spectrum of agricultural production and market integration, nutritional status and food security, gender equity and poverty. It also enables rapid characterizations of both farm practices and farm performance, thus allowing one to group and assess farming households around a variable of interests; in our case access to quality cassava planting material. Because of its standardized indicators, RHoMIS also allows comparison across geographies and monitoring across time, which is useful for multi-country or region and time-bound interventions.

In total, 390 farming households were surveyed in four districts of Rwanda, where cassava production is most prevalent: Ruhango, Nyanza, Kamonyi, and Bugesera. Data was collected in November and December of 2019. Using the number of farming households in each district as a baseline, a sample size sufficiently large to detect the diversity of the farming households, was calculated with a 95% confidence interval and 5% margin of error. The resultant minimum sample for each district was divided proportionally across two randomly selected sectors of the same district (Figure 1). The determined sector sample sizes were then evenly distributed across four random villages with the district.

Following Hammond et al. (2020), enumerators were instructed to start at the center of the selected villages. Then, a random direction and number (n) were generated. The enumerator had to select the nth house based on the generated number, in the generated direction. Following completion of the interview, enumerators returned to the center of the village and this process was repeated until the predetermined number of households to be surveyed in the village was reached. Open Data Kit (ODK) forms were pre-installed on Android tablets to collect the data.

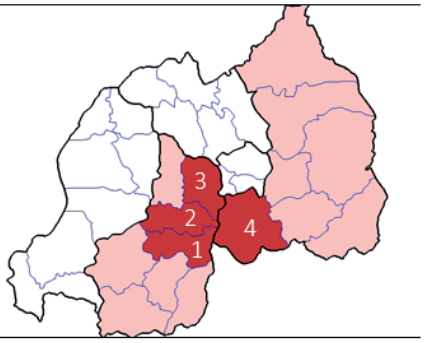
nr	District	Sectors	Households	Map
1	Ruhango	Ruhango	49	
		Mbuye	49	
2	Nyanza	Kigoma	49	
		Ntyazo	49	
3	Kamonyi	Nyarubaka	40	
		Musambira	40	
4	Bugesera	Nyarugenge	54	
		Mayange	54	

FIGURE 1. Number of households interviewed per district and sector. Districts are shown on the map of Rwanda. (image modified from source: https://nl.wikipedia.org/wiki/Bugesera)

Developing farmer typologies

For the survey, more than 60 variables were selected as potential explanatory variables for farming household diversity, in particular in relation to the households' access to quality cassava seed. These variables included demographic, agronomic, economic and cassava-specific variables. This list was reduced through knowledge of the sites, understanding of seed systems, and logical analysis, to 17 variables (Table 1). Data for these variables were examined to identify missing data and outliers. Two multivariate statistical steps were applied to develop our farmer typologies: i) reducing the dimensionality of the data through the application of principal component analysis (PCA); and ii) cluster analysis for partitioning into clusters.

Table 1. Variables used for farm typology development.

Variable	Unit
Household	
Household Head Age	Age
Household Head Sex	Male/Female
Household Head Marital Status	Categorical
Years on Farm	Years
Assets	
Radio Ownership	Yes/No
Asset Count	Number of assets
Farm Structure	
Inorganic Inputs Count	Number of inputs
Total Livestock Units	Number of TLUs
Cassava Production Sold	Yes/ No
Positive Farm Changes	Custom Score
Economic	
Total Crop Income	USD
Access to Finance	Yes/No
Credit Received	Yes/No
Seed Systems	
Cassava Seeds Sold	Yes/No
Seed Multiplication as a Business	Yes/No
Improved Varieties Used	Yes/No
Improved Varieties Count	Number of varieties

Principal component analysis

To reduce the dimensionality of the dataset, we employed principal component analysis (PCA; Jolliffe, 2002). PCA has been widely employed in typology generation in farming systems (e.g. Alvarez et al., 2018; Kuivanen et al., 2016; Lopez-Ridaura et al., 2018). The analysis was performed using the ade4 package of R (Dray and Dufour, 2007; R Core Team, 2019). We retained relevant principal components through application of two criteria: i) Scree test; and ii) that the PCs had an eigenvalue greater than 1 (Kuivanen et al., 2016). Application of these criteria resulted in the retention of 5 principal components (Table 2).

Table 2. Eigenvalues and variance (individual and cumulative) of the five principal components from PCA.

Principal Component	Eigenvalue	Variance (%)	Cumulative Variance (%)
1	3.8	19	19
2	2.4	12	31
3	2.2	11	42
4	1.9	9	51
5	1.6	8	59

Cluster analysis

We used the partitioning around the medoids method for clustering (PAM; Reynolds et al., 1992). PAM identifies a medoid observation (in this case farm) that is most representative of a cluster and seeks to reduce the dissimilarity of other observations to that medoid (Reynolds et al., 1992). To develop the dissimilarity matrix for PAM, we followed Hammond et al. (2020) and applied the Gower method (Gower, 1971), which allows for inclusion numerical, ordinal, and categorical data types. To determine the optimal number of clusters to be retained, we reviewed the silhouette width metric, with the silhouette width being highest for 7 clusters. The inherent structure of the clusters was then evaluated (e.g. mean and modal values for each variable and cluster).

Testing for the significance (α 0.05) of variables between clusters was done using the chi-squared test for binary variables, one-way ANOVA for parametric continuous variables, and Kruskal Wallis for non-parametric continuous variables. When a significant difference was identified via Kruskal Wallis, further comparison between groups was done via Mann-Whitney U tests with an adjusted alpha of 0.002. To further

characterize the clusters they were assigned a descriptive name based upon on the variable(s) that most distinguished them from other clusters.

Cassava seed tracing

An improved variety, NASE14, introduced in response to CBSD outbreak, was traced via snowball sampling (Goodman, 1961). Data was collected in January and February 2020. The seed tracing study started with a subsample of 61 farmers selected randomly from the household survey respondents with a random number generator in Excel. Farmers were selected form the same districts, Ruhango, Nyanza, Kamonyi, and Bugesera, as the respondents of the typology survey. All the participants in this subsample were interviewed about their cassava seed sourcing practices. If the farmer grew NASE14, we traced from where the farmer obtained this variety until a formal actor such as a seed multiplier, NGO or RAB was reached. This resulted into an additional 11 interviews with farmers that exchanged NASE14 seed and who provided links between the surveyed farmers and formal actors. The data from the typology analysis were linked to the tracing data.

To visualize transactions, the data from the seed tracing study was further analyzed following the protocol for 'seed tracing' (Kilwinger and Buddenhagen, 2021). This resulted in a 'node-list' and an 'edge list'. The nodes represented the interviewed actors. Additional information, such as the type of actor and demographic information were included in the node list. The edge list was based on transactions of NASE14 planting material between the actors (nodes). Similarly, additional information on the transactions such as quantity, frequency, and transaction type was included in the edge list. Using this node and edge list, a network graph was created in the Excel add-in 'NodeXL'.

In addition, a list of seed multipliers provided with NASE14 seed was obtained from Rwanda Agricultural and Animal Resources Development Board (RAB) (the national institution mandated to release varieties and provide the first clean seed). This resulted in the identification of 16 seed multipliers who were then asked about their selling of cassava stems.

RESULTS

Cassava farmer typologies

The 390 farmers interviewed during the RHoMIS survey were grouped into 7 clusters using principal component analysis (Table 3). There seemed no geographic aspect to this response as farmers in all clusters were scattered over the sample areas.

Table 3. Demographic and cassava farming information of the 7 generated farmer typologies via household survey data (n = 390). All presented values are means or proportions. Letters indicate statistical differences (α 0.05) tested with the chi-squared test for binary variables, one-way ANOVA for parametric continuous variables, and Kruskal Wallis and Mann-Winey U for non-parametric continuous variables. Variables that were not significant or violated assumptions for statistical testing are indicated as 'ns'.

Cluster (n)	1 (39)	2 (138)	3 (51)	4 (76)	5 (34)	6 (19)	7 (33)	Total
HH head sex is male (%)	100^{a}	100^{a}	90^{a}	95^{a}	0^{b}	0^{b}	15^{b}	60
HH head age	50^{b}	45^{a}	41^{a}	43^{a}	51^{b}	54^{b}	59^{c}	47
HH head marital status is married (%)^{ns}	97	93	90	91	12	16	18	61
HH head has no formal education (%) ^{ns}	46	54	67	45	65	84	85	58
HH members	5.43^{ab}	5.44^{a}	5.03^{ab}	5.47^{a}	4.52^{ab}	4.10^{ab}	4.12^{b}	5.13
Females in HH are involved indecision making (%)	52^{a}	53^{a}	62^{b}	53^{a}	89^{c}	9^{ac}	89^{c}	70
Farm size (ha)	0.69^{ad}	1.02^{a}	0.33^{bc}	1.22^{a}	1.17^{a}	0.28^{bcd}	0.64^{ac}	0.76
Years on farm	28^{bc}	22^{c}	21^{c}	22^{c}	30^{b}	33^{ab}	40^{a}	28
Market travel time (minutes)	41^{a}	62^{ab}	74^{b}	64^{ab}	52^{ab}	56^{ab}	65^{ab}	59
Number of assets household owns/has access to	2.2^{ab}	2.4^{a}	0.7^{c}	2.5^{a}	2.0^{ab}	1.7^{b}	0.3^{c}	1.7
Number of inorganic inputs used by household last year	1.5^{a}	1.4^{a}	0.4^{b}	1.5^{a}	1.0^{ab}	0.8^{ab}	0.4^{b}	1.0
Total livestock unit (TLU)	0.94^{ab}	0.84^{a}	0.76^{ab}	1.09^{a}	0.79^{ab}	0.46^{ab}	0.44^{b}	0.76
Livestock diversity (types of livestock owned by household) ^{ns}	1.8	1.6	1.5	2.0	1.3	1.0	1.4	1.5
Crop diversity (number of crops grown by household)^{ns}	3.7	3.5	3.4	3.9	3.7	3.3	3.6	3.6
Total crop income (RWF^{2})	110^{bc}	231^{cd}	65^{ab}	298^{d}	183^{cd}	104^{bcd}	27^{a}	107
Number of positive farm changes last 4 years	2.1^{ab}	2.4^{a}	1.7^{ab}	2.8^{a}	2.1^{ab}	1.5^{ab}	1.2^{a}	2.0
Most important crop is cassava (%)^{ns}	71.8	71.7	66.7	72.4	73.5	57.9	51.5	69.0
Farm area dedicated to cassava (%)	41^{ab}	53^{a}	41^{b}	50^{ab}	54^{ab}	51^{ab}	39^{b}	47
Total area cassava (ha)	0.31	0.59	0.14	0.69	0.65	0.15	0.26	0.48
Cassava yields (kg/ha) ^{ns}	4016	3138	4471	3925	3271	3698	3973	3785
Share of cassava production sold (%)	29^{abc}	34^{ab}	25^{c}	45^{a}	34^{abc}	16^{bc}	13^{c}	28
Has enough quality cassava seed (%)	31^{abcd}	46^{d}	28^{c}	37^{abcd}	50^{bd}	47^{abcd}	24^{ac}	39
Aware of benefits certified seed (%)	92^{ab}	80^{bc}	77^{cd}	92^{a}	82^{abcd}	80^{abcd}	64^{d}	82
Uses improved seed (%)	38^{a}	36^{a}	10^{b}	40^{a}	27^{ab}	15^{ab}	15^{b}	31
Pays for quality cassava seed (%)	26^{a}	30^{a}	31^{a}	53^{b}	27^{a}	16^{a}	18^{a}	32
Distributes quality cassava seed (%)^{ns}	33	49	37	55	41	36	33	44
Sells cassava seed (%)^{ns}	80	97	96	98	97	89	87	94
Wants to be a seed multiplier (%)	0^{a}	100^{b}	86^{c}	97^{b}	100^{b}	0^{a}	21^{d}	76
Has access to finance for cassava farming (%)	36^{ab}	45^{b}	35^{ab}	68^{c}	32^{ab}	37^{ab}	24^{a}	44
Has attempted to get credit for cassava farming (%)	5^{ab}	0^{c}	14^{ab}	100^{d}	12^{ab}	21^{b}	3^{a}	25

The largest category of farmers were clustered as type 2 (35%) (Table 4). These farmers were interpreted to be 'average cassava farmers'. They are generally male headed households with relatively high levels of assets and relatively large farm sizes, but relatively poor cassava productivity (Table 3). The second largest cluster was type 4. We named this group 'professional farmers'. They are generally male-headed households, and have the most assets and livestock and the largest farm sizes. The household heads were relatively highly educated and attained the highest revenue from their crops out of all the typologies.

Farmers clustered in type 1 and 3 are both generally male-headed households who mainly differ based on age of the household head and farm size. With a mean of 50 years, the household heads of typology 1 were significantly older than those of other male-headed typologies. With a mean of 41 years, the household heads of type 3 were the youngest of all developed typologies. Type 1, named 'older farmers', had higher education, more assets, and used more farm inputs. Type 3, named 'small-scale farmers' had the smallest farms, fewest assets and used the least inputs of the male-headed typologies. Despite having less resources available, the productivity of these households is high, which is not uncommon for small farms of young households.

Table 4. Descriptions of the farmer typologies and their representativeness (%) in the whole sample (n=390)

Type	Description of farmer typology	%
1	**Older farmers** Male-headed households, married, primary education, older household head, close to market, high asset count, high use of inputs, no interest in being a seed multiplier	10%
2	**Average cassava farmers** Male-headed households, married, no education, larger farm size, relatively low yield, high asset count, interested in being a seed multiplier.	35%
3	**Small-scale farmers** Male-headed households, married, no education, small farms but with high yields, younger household heads, female partners more often involved in decision making, low asset count, low use of inputs, little use of improved cassava seed, low income from crops, sells relatively little cassava.	13%
4	**Professional cassava farmers** Male-headed households, married, primary education, largest farms, highest asset count, high use of inputs, high use of improved cassava seed, pays for quality seed, access to finance for cassava farming, highest income from crops.	19%
5	**Better-off female-headed households** Female-headed households, widowed, no education, large farm, high asset count, medium use of inputs, relatively low yields, higher access to quality seed, interested in being a seed multiplier, high income from crops.	9%
6	**Small-scale female-headed households** Female-headed households, widowed, no education, smallest farms, medium assets, have access to quality seed, sells relatively little cassava, no interest in being a seed multiplier.	5%
7	**Elderly poor female- headed households** Female-headed households, widowed, no education, older household head, more years on farm, medium farm size, fewest assets, least use of inputs, sell smallest part of their cassava, have the lowest crop income.	8%

The last three types 5, 6 and 7 are all female-headed households (mostly widowed, and some divorced or single). Female-headed households together made up for 23% of the households surveyed. Type 5, 'better-off female-headed households' had larger farm sizes, perceived themselves to have better access to quality cassava seed, and had a relatively high asset count as well as crop income. Type 6 'small-scale, female-headed households' are characterized by very small land sizes. Type 7 'elderly, poor, female-

headed households' seemed to be in the most vulnerable position: the household heads are older, they have the least assets, use the least farm inputs, reported the lowest crop income, and grow the largest share of cassava for home consumption. The average reported crop income of type 7 (RwF 27,000) is about a quarter of the reported crop income of type 6 (RwF 104,000), even though they have on average twice as much land available (Table 3). RwF 1,000 equals approximately 1 USD.

Seed sourcing practices

Farmers in the household survey (n = 360) grew between 1 and 5 cassava varieties with a mean of 1.84 (SD = 0.74). In total 46 varieties were grown by farmers. The majority (28) were local varieties, also known as landraces, of which many (20) were grown by 1% or less of the farmers (Appendix 1). Of the remaining 18 varieties, 16 were introduced in Rwanda since 1975, and of 2 the introduction date is unknown. Via a list provided by RAB, 10 of those varieties were identified as improved and officially released since 2005. NASE14 was the variety grown by most farmers (51%). Besides its dual resistance for CMD and CBSD, farmers are fond of the variety because it has multiple purposes. The sweet taste makes it usable in fresh form (boiled roots are a common local dish), and because it is heavy, it is suitable for flour processing as well. These traits make the variety fetch a high market price, providing the household with both food and income.

NASE14 was officially released in 2018 (after being tested at trials), but had been with farmers since introduction from Uganda in 2015 (IITA, 2015). When preferred by farmers, varieties tend to spread from demonstration plots before being officially released. For example, Macadamia, the most grown improved variety after NASE14 (grown by 44%), was tested on research stations around 2009. It never got formally released until 2021 because researchers found its dry matter content too low. Farmers nevertheless kept growing the variety because of its early bulking and multiple end uses.

The majority of the farmers (85%) grew one or more varieties introduced after 2005 (Table 5). Of the farmers classified as older farmers (type 1) the fewest grew improved varieties (77%) and of the professional farmers (type 4) the most (96%). Slightly less than half of all the farmers (48%) grew only improved varieties. Of the professional

farmers most farmers grew only improved varieties (57%) and of elderly poor FHH (type 7) the least (33%). In general, 26% of the farmers grew both improved and local varieties. A few farmers grew only local varieties (6%). Of the better-off FHH (type 5) most farmers grew only local varieties (12%) whereas none of the professional farmers grew only local varieties. The varieties of which the original source was traced were mainly informal, 67% came from a fellow farmer. The majority of farmers started growing improved varieties between 2014 and 2019 with the highest number of farmers reporting 2017 as the year they originally sourced an improved variety.

On average, 38% said that they have access to high quality cassava seed. 'Quality' was not defined during the interviews. Thus, if farmers said that they have access to quality cassava seed, this was according to their own perceptions[3] . Among all types, most farmers who claimed that they did not have access to quality seed, also did not know where they could access high quality material. Only 20% said they knew sources with quality material available. Thus, in general 43% of the farmers did not have access to quality material nor knew where they could access it. The perception of having access to quality cassava seed seemed more variable among farmer typologies compared to access to improved varieties. In particular many elderly, poor female-headed households (type 7) perceived a lack of access (67%), especially compared to better-off female-headed households (29%).

Most farmers who said they have access to quality seed perceived informal sources (their own farm and fellow famers) as the main source. Professional cassava farmers were the most likely to access their seed from formal sources. A small percentage of professional cassava farmers accessed quality seed from seed multipliers (4%), cooperatives (1%) and RAB (3%). An even smaller percentage of older and average cassava farmers (types 1 and 2) accessed quality seed from formal sources. Other typologies, small-scale farmers and all female headed households (type 3, 5, 6 and 7), said they did not use formal sources to access quality seed, and only a few (≤6%) perceived them as potential sources. They perceived their own farm and fellow farmers as sources for quality seed

[3] Formal sector standards tend to aim for varietal purity, while, by contrast, farmers may favor a degree of variety heterogeneity, especially when sowing in risk-prone and unpredictable environments. Evidently, assessments of quality vary according to the assessor (Sperling et al., 2008).

Table 5. The percentage of farmers per typology growing improved cassava varieties and the percentage of farmers per typology who perceived themselves as having access to quality seed (n=390). The sources farmers use to access quality cassava seed, and the sources they would use to access cassava seed (n=390)

	Typology ‡							
Variable	1	2	3	4	5	6	7	Total
Number of cassava varieties grown	1.85	1.78	1.86	1.99	1.62	1.79	1.94	**1.84**
Grows one or more improved varieties	77%	80%	84%	96%	85%	89%	85%	**85%**
Grows NASE14	49%	44%	49%	62%	59%	53%	48%	**51%**
Grows only improved varieties	36%	51%	51%	57%	53%	37%	33%	**48%**
Grows one or more local varieties	36%	28%	31%	29%	32%	32%	36%	**31%**
Grows improved and local varieties	28%	21%	29%	29%	26%	26%	33%	**26%**
Grows only local varieties	10%	8%	4%	0%	12%	5%	6%	**6%**
Sources new varieties from fellow farmers §	90%	69%	100%	59%	67%	100%	50%	**67%**
Sources new varieties from seed multipliers §	0%	22%	0%	20%	20%	0%	50%	**19%**
Sources new varieties from RAB §	10%	7%	0%	16%	7%	0%	0%	**10%**
Sources new varieties from NGO projects §	0%	2%	0%	5%	7%	0%	0%	**3%**
Has access to quality cassava seed	31%	46%	27%	37%	50%	47%	24%	**38%**
Knows where to access quality cassava seed	28%	13%	25%	30%	21%	11%	9%	**20%**
No access nor knows where to access quality cassava seed	41%	41%	47%	33%	29%	42%	67%	**43%**
Sources quality cassava seed from own farm	28%	32%	24%	18%	32%	26%	9%	**24%**
Sources quality cassava seed from fellow farmers	8%	25%	16%	22%	26%	26%	18%	**20%**
Sources quality cassava seed from seed multipliers	0%	2%	0%	4%	0%	0%	0%	**1%**
Sources quality cassava seed from RAB	3%	1%	0%	3%	0%	0%	0%	**1%**
Sources quality cassava seed from cooperative	0%	0%	0%	1%	0%	0%	0%	**0%**
Would source quality cassava seed from fellow farmers	18%	11%	16%	24%	18%	11%	9%	**15%**
Would source quality cassava seed from Seed multipliers	8%	4%	6%	9%	3%	5%	0%	**5%**
Would source quality cassava seed from RAB	5%	1%	2%	8%	3%	0%	0%	**3%**
Would source quality cassava seed from cooperative	5%	1%	0%	4%	0%	0%	3%	**2%**

‡ Farmer typologies: 1 = Older farmers; 2 = Average farmers; 3 = Small-scale farmers; 4 = Professional farmers; 5 = Better-off FHH; 6 = Small-scale FHH; 7 = Elderly, poor FHH

§ Data used from seed tracing dataset with different sample sizes, farmers could mention the original source for more than 1 variety resulting in 159 observations : 1) n=10; 2) n=54; 3) n=5; 4) n=64; 5) n=15; 6) n=5; 7) n=6.

Seed replacement dynamics and purchasing behaviour

In total, 52 farmers were interviewed that grow NASE14 to identify the original source of the variety. Of these farmers 41 participated in the household survey and were assigned to a typology. Through snowball sampling 19 additional farmers, that provided surveyed farmers with NASE14 seed, were identified. Of these farmers 11 could be reached for a follow-up interview to further trace where they sourced NASE14. The majority of the farmers identified in the seed tracing study were male-headed households (types 1 to 4). These were also more abundant in the typology survey (77%) than female-headed households (Table 3).

Farmers obtained NASE14 for the first time between 2014 and 2019 and accessed it from several sources: sector offices (SO), non-governmental organizations (NGO), seed multipliers (M) and fellow farmers (FF) (Figure 2). Several farmers mentioned they sourced seed from a seed multiplier, but these were not officially recognized as such by RAB (M*). SOs, Ms and NGOs got NASE14 planting material from RAB. RAB in turn obtained NASE14 germplasm from the National Agricultural Research Organization (NARO) in Uganda in 2014. Only 2 of the M*s could be identified for a follow-up interview and got NASE14 from RAB. Where the other M*s originally sourced NASE14 could not be traced.

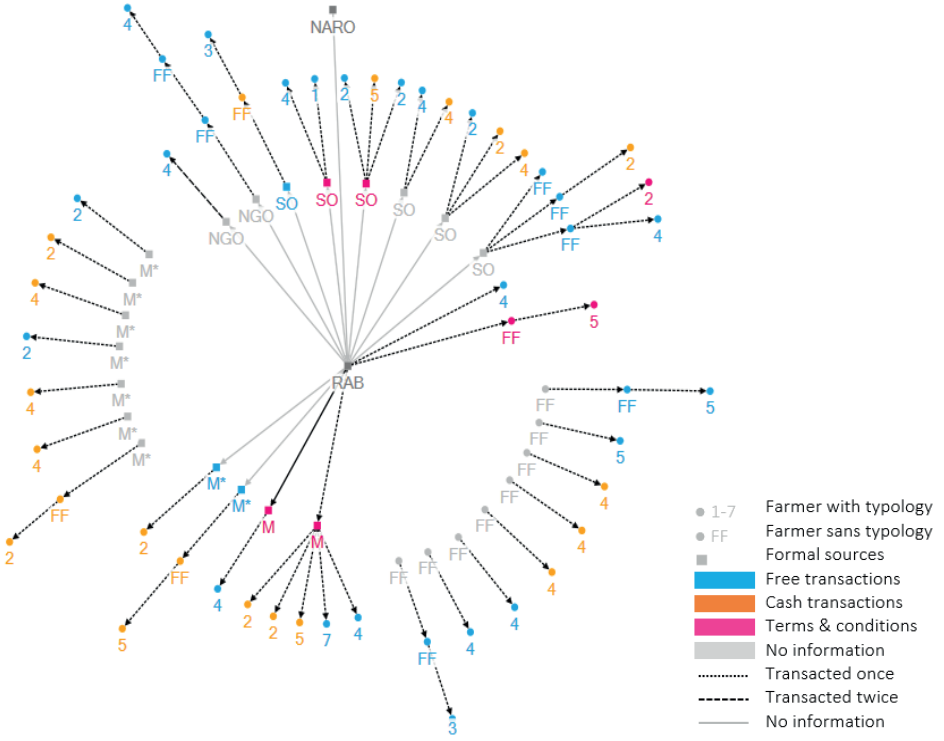


FIGURE 1. Visualisation of tracing NASE14. The arrows indicate exchanges of seed of cassava variety NASE14. The types of actors are indicated using shapes and numbers. Circles represent a farmer assigned to a typology (1-7) or a farmers without assigned typology (FF). Squares represent the formal sources: sector offices (SO), non-governmental organisations (NGO), NARO, RAB, and official (M) and unofficial seed multipliers (M*). The colour of the shapes represents the transaction type: blue = free; orange = cash; pink = terms and conditions. The line style represents the frequency of transactions: dotted lines once, dashed lines twice and solid lines more than twice. Grey shapes and lines indicate no information on transaction type and frequency was available.

None of the seed multipliers had to pay with cash for NASE14 planting material. Of the 16 seed multipliers officially recognized by RAB, 10 said they obtained the seed from RAB free of charge. They obtained the material between 2014 and 2018. The remaining six multipliers said they had received the seed with certain terms and conditions. This mainly entailed them sharing the same amount of seed as they received from RAB with fellow farmers, as part of RAB's strategy to disseminate new improved varieties. Seed multipliers each obtained between 8000 and 200,000 NASE14 cassava cuttings from RAB. The number of farmers each multiplier provided with seed varied between 20 and 400. Some seed multipliers provided farmers with NASE14 stakes free of charge and others for cash. The number of cash transactions varied between 10% and 100% among multipliers, with a mean of 59%.

Several farmers obtained NASE14 seed from sector offices or NGOs. Three employees at sector offices could be contacted and they indicated they either got seed from RAB free of charge or under terms and conditions. They reported to have obtained between 1,000,000 and 2,000,000 stems. Sector offices did not further multiply the material, they only distributed. This could be the reason why the volumes of seed provided by RAB were higher compared to the volumes supplied to multipliers. Not from all formal actors information on distributed volumes of seed could be identified, meaning their relative importance could not be further visualized.

In general, 39% of the farmers made a cash investment to acquire NASE14 (Table 6). Only farmers classified as type 2, 4 and 5 made cash investments while acquiring NASE 14 seed, whereas types 1, 3 and 7 obtained it for free regardless of where it was sourced. Compared to the original sources of all varieties, NASE14 was most often sourced from formal sources. Interestingly, Macadamia was originally sourced from fellow farmers by 74% of the farmers, but was more often paid for with cash than NASE14. Similarly, it were type 2,4 and 5 farmers who made those cash investments (data not shown). None of the farmers accessed Macadamia via a government program.

With one exception, none of the farmers sourced NASE14 seed off-farm more than once (Figure 2). On the other hand, all the farmers multiplied the NASE14 seed themselves after the first acquisition, and 80% of the farmers went on to share this multiplied seed

with fellow farmers. Most farmers (78%) perceived that the quality of the material remained unchanged between them first acquiring it and after they multiplied it, 10% perceived that the quality increased after self-multiplication, and 12% perceived that it decreased.

Nearly all farmers (82%) reported having experienced viral diseases in their cassava fields in the past The severity of the disease infestation on the farm at the worst moment, expressed as % of infected plants, ranged between 10 and 100 with a mean of 52%. The severity of the disease at the time of the interviews ranged between 0 and 40 with a mean of 2%. The practices farmers used to control the disease were: sourcing new seeds (59%), rogueing (41%), and planting improved varieties (39%). The majority of the farmers (90%) said that they had never received training about maintaining the sanitary quality of seed.

Table 6. Varieties original source and transaction type. 188 transactions were recorded from the subsample of 72 farmers.

	All varieties	NASE14	Macadamia
Original source			
Fellow farmer	67%	40%	74%
Seed multiplier	19%	28%	23%
NGO project	3%	4%	3%
GO project	10%	28%	0%
Transaction type			
Free	63%	54%	46%
Cash	34%	39%	54%
In kind/under conditions	3%	7%	0%

DISCUSSION

Farmers access to, and investments in, new varieties

More than 85% of the surveyed farmers were growing improved cassava varieties that were formally registered after 2005. A study conducted in 2007 found that 83% of the surveyed farmers in Rwanda grew only local varieties (Night et al., 2011), suggesting a rather effective diffusion and high adoption of improved cassava varieties[4]. The majority

[4] In the study of Night et al., 2011 large differences among districts were identified (15% vs. 100% of farmers growing only local varieties in Bugesera and Ruhango respectively), which were not identified in this study (data not presented).

of farmers started growing improved varieties between 2014 and 2019, making it plausible that adoption was in response to high disease pressure. While farm typologies did not show major differences in the use of improved varieties, the sources through which farmers had accessed them varied. The majority of farmers, mostly, if not entirely, used informal seed sources to acquire new varieties. Farmers labelled as 'professional farmers' (type 4) most often used formal sources to acquire new varieties, although the majority of them still reported to use informal sources. Patterns of farmer-to-farmer seed diffusion involving social barriers are common (Almekinders et al., 2020; Coomes et al., 2015; Tadesse et al., 2017), and could have important implications for introduction points of new varieties and other activities. Despite influencing the timing and other acquisition conditions, these social barriers seemed to have little effect on who the variety eventually spread to.

The efforts of RAB and partners to introduce NASE14 seemed successful as half of the farmers grew the variety. Macadamia was also adopted by many farmers and cash transactions to obtain the variety were even more reported than cash transactions for NASE14. This suggests that markets for new cassava varieties emerge naturally when they have desired traits. Nevertheless, none of the formal sources multiplying and/or distributing NASE14 (and likely Macadamia) had to pay for the material they received from RAB. To move away from aid-based seed systems, it seems important to determine at which stage of the seed value chain commercialization should start. Many studies that report the emergence of commercial seed enterprises for vegetative propagated staple crops in Sub-Saharan Africa do not report where and how sellers obtain their material in the first place (for example Bentley et al., 2020; Rachkara et al., 2017). When prices are based on the actual costs of breeding and early generation seed production, it is unknown if actors along the value chain would still be willing-to-pay, and if investments can be profitable considering the (highly fluctuating) prices of cassava roots.

The finding that 59% of the farmers acquired NASE14 seed from seed multipliers through cash transactions supports the assumption that there are commercial opportunities for seed of new cassava varieties. Our results indicate that the NASE14-related cash transactions were one-time acquisitions, made during a period of severe

disease outbreak; all farmers thereafter multiplied NASE14 for their own use and the majority shared their multiplied seed with fellow farmers. This initial demand for seed of the new variety can give the impression that there is sufficient purchase commitment, but as the variety becomes embedded in the informal seed system, the commercial advantages evaporate (Tripp, 2003). For seed businesses to thrive on new varieties, they would need a steady stream of newly released varieties, which requires linkages breeding and seed programs. In addition, ensuring a constant flow of new varieties could raise other problems: effective campaigns for variety replacement can result in a loss of land races, agrobiodiversity, and in-situ conservation (Pautasso et al., 2013; Thrupp, 2000), and the frequent release of new varieties could complicate choices for farmers (Stone, 2007).

Farmers access to, and investments in, quality cassava seed

Farmers access to quality cassava seed seemed more variable than their access to new varieties. Many farmers reported a lack of access to quality cassava seed. The definition of 'quality seed' was not clarified to them, nor did we ask them for a definition, so the term was open ended and could carry different meanings. Better-off female-headed households (Type 5) were the most likely to perceive themselves as having access to quality seed but used informal sources to acquire it. Most elderly farmers, small-scale farmers, and poor female-headed household perceived themselves to have limited access to quality seed (Type 1,3 and 7). Professional farmers (Type 4) also perceived that they had relatively little access to quality seed although it was this group that made most use of formal sources. This is possibly due to a different or stricter definition of quality seed among professional farmers. Nevertheless, all types of farmers, even professional cassava farmers, most frequently used informal sources to access high quality cassava seed.

Although many farmers reported a lack of access to quality seed, the question remains how this would translate to purchase commitments from seed businesses since its mainly te poorer households who perceive to have limited access. Further research is needed to provide insights in farmers' willingness-to-pay for quality seed and differences among typologies. Furthermore, for businesses to thrive on the provision of clean seed, seed

degeneration patterns need to be understood in order to make predictions on the number of seasons it takes for quality declared and/or certified seed to become advantageous over farm-saved seed. NASE14 seed was generally only acquired once from an off-farm source. Farmers thereafter recycled their material, and the majority reported the quality of their multiplied material had not decreased so far. Seed degeneration rates in farmers' fields are hard to predict. They depend on many aspects such as the environment, management, and variety (Shirima et al., 2019; Thomas-Sharma et al., 2016). Information on seed degeneration should be accompanied by adequate data on yield differences and market prices to show farmers that investments in clean seed are profitable. This information forms the basis of a proper advice on replacement rates, which in turn would be an input in the sales projection for seed busines models: it would define a value proposition and profit formula.

Proper on-farm management practices of vegetative propagated planting material, such as rogueing and positive seed selection, as part of the integrated seed health management approach, are potentially as effective as use of certified seed (Thomas-Sharma et al., 2017). This could allow farmers who, for different reasons, are not able or willing to buy clean seed to produce their own quality seed at lower costs. But, promoting better on-farm management of seed quality would also diminish the demand from seed businesses: fewer farmers would buy clean seed and/ or would buy it less frequently. A cassava seed degeneration study in Tanzania showed that varieties have different degeneration patterns: 'strong', 'moderate,' 'mild,' and 'delayed' (Shirima et al., 2019). This insight brings us to another important element of the integrated health management approach (Thomas-Sharma et al., 2016) and a dilemma in the discussion on commercial opportunities for vegetative planting material: market demand for resistant varieties evaporates as they get absorbed in the informal seed system, and demand for clean seed likely decreases due to the milder degeneration patterns of those varieties.

Tailored business models or an 'all or none' approach

Developing farmer typologies and exploring their seed sourcing practices, seed replacement dynamics, and purchasing behavior can assist in designing tailored seed business models. When diversity in seed systems is acknowledged, an integrated seed

system development appears to be a suitable approach (Louwaars and De Boef, 2012). In such approach it has been proposed that seed system interventions should not aim to convert all farmers to use commercial seed, but rather to identify those who benefit most from using improved quality seed (Staver et al., 2010). The seed tracing study showed that better-off and more commercial oriented farmers make cash investments in seed, while others rely on seed multiplied by those or otherwise free available seed. This information can support the development of client profiles for commercial seed businesses while simultaneously encouraging informal seed access for farmers who cannot, or do not prefer to, use formal sources.

However, such differentiated approaches also limit the potential clientele of commercial seed businesses. For example, several seed multipliers in our study mentioned they had received their seed from RAB under 'terms & conditions', which meant they had to share their multiplied material with fellow farmers, or return a part of their multiplied seed to be distributed. This approach, undoubtedly meant to spur the diffusion of the new varieties, is in contrast with the envisioned business models which would encourage client-farmers to cash purchase from commercial seed businesses. Similarly, integrated seed health approaches suggest reducing farmers' dependency on external seed sources by, for example, using disease resistant varieties and applying positive selection. These strategies will plausibly affect the commercial demand for clean seed. This does not mean there is no potential for tailored seed business models at all, but rather that they need to be properly coordinated and well-focused. A project estimating the potential for cassava seed businesses in Nigeria, 'BASICS', came to similar conclusions and advises an "All or None" approach. This means that all interventions regarding the cassava value chain need to be carried out in alignment in order to avoid one intervention undermining the other (Nitturkar, 2018).

CONCLUSION

Commercial seed business models are currently being advocated as a route to developing economically sustainable seed systems providing farmers with materials that overcome a range of production challenges. In this study we developed farmer typologies to inform in the design of seed system interventions, and more specifically

to collect data that would assist the development of tailored seed business models. There was a high level adoption of improved varieties among all established farm typologies. Adoption of improved varieties may have happened in response to high disease pressure. Our results indicate that markets for cassava seed emerge to acquire new varieties with desired traits. Cash investments were mainly made by better-off farmers, whereas poorer farmers relied on free access to seed. Many farmers reported a lack of access to quality seed in general, but identified mainly informal sources as potential sources. Since the improved variety NASE14 got introduced in Rwanda early 2015, the majority of farmers used a formal or other off-farm source only once to acquire the variety, and thereafter recycled their material. Farmers generally perceived their recycled material remained of sufficient quality so far.

Based on farmers current seed sourcing strategies, we identified several knowledge gaps that are relevant for the development of viable seed business models. Clarifications and explications on differences between farmers and their willingness-to-pay, the roles of seed degeneration, and cost-benefit analyses seem important requirements for the development of economically sustainable seed business models. To provide cost-benefit analyses that seed businesses could use, it first needs to be defined which parts of the cassava seed value chain remain aidbased or are part of public expenditure, and where commercialization should start. This information can further be used for value propositions and profit formulas of seed business models. In addition, the advocated routes of seed system development have contrasting underlying goals: supporting farmers with free seed or promotion of integrated seed health approaches may affect commercial business models. By acknowledging the differences between farmers, tailored business models might have a high potential impact, but different interventions in the value chain will need to be coordinated to ensure one intervention does not undermine the other.

LIMITATIONS

This study made use of surveys and many variables are self-reported estimations of farmers. Self-reporting is not uncommon despite the biases that may occur. The cassava yields reported by farmers were low (3–4 t/ha). Besides deviations due to self-reported estimations, reported yields are likely lower due to the type of cropping system. It is common in Rwanda to intercrop cassava with other crops such as maize and beans. This would lower the cassava yield/ha but does not directly mean the productivity/plant is low. In a survey from 2007, 78% of the farmers reported they intercropped their cassava (Night et al., 2011), but it cannot be assumed this number was similar in 2020. It is a limitation of this study that the type of cassava cropping system was not recorded, especially as this has influence on disease incidence (Night et al., 2011). Finally, snowball sampling is a useful method for a seed tracing studies, but in practice it turned out to be difficult to follow-up on identified actors. Especially actors far away, or actors with weak social ties between them, are difficult to follow up. This might create a biased image undervaluing the importance of seed exchange among farmers with weak ties or large distances between them.

CHAPTER
Three

Culturally embedded practices of managing banana diversity and planting material in central Uganda

Publication information

Adapted version of: Kilwinger F, Rietveld A, Groot J and Almekinders C. (2019). Culturally embedded practices of managing banana diversity and planting material in central Uganda. Journal of Crop Improvement, 33(4), 456-477.

ABSTRACT

Formal seed systems aim to provide farmers with high quality planting material that meets evolving demand and cultivation challenges. East African banana (Musa sp.) systems rely strongly on informal seed exchange. For seed system interventions to have a larger and more sustainable impact in such a context, it is necessary to better understand the informal seed system. We studied the management and replacement dynamics around banana suckers and mats by smallholder farmers in Central Uganda. Data were collected through Focus Group Discussions (n=4) and semi-structured interviews (n=23). This study showed that, on average, banana farmers grew 10 different banana cultivars to ensure year-round harvesting and to accommodate multiple consumption and cultural needs. They included cultivars from the formal seed system within their portfolios of banana cultivars while also conserving cultivar diversity. Farmers used a broad array of evaluation criteria to select suckers and preferred to use known sources to assure seed quality. Household characteristics, such as age or wealth, are determinants of mat management and replacement. We concluded that a flexible blend of formal-informal approaches to developing the banana seed system is needed to meet the multiple needs of farm households and to support them in improving productivity and dealing with emerging challenges.

INTRODUCTION

The word agriculture combines two connected elements, 'agri' and 'culture', indicating that food production forms an integral part of the culture of those who grow the crops and manage the land (Pretty, 2002). Seed systems are especially interesting because their combined social-cultural elements, such as the use of diversity for different purposes and the ways in which seeds are shared, reflect and shape relationships among farming people (Almekinders and Louwaars, 1994; Coomes et al., 2015). Seed systems are also of interest to those who want to improve agricultural production. Access to high quality seed is considered to be an important pathway out of poverty for smallholder farmers (Cromwell, 1990) and is the basis of multiple development projects. To provide smallholder farmers with high-quality seed, governments, Non-governmental organizations (NGO) and other organizations concerned with agricultural development, engage in 'seed-system interventions'. These interventions are usually based on strengthening 'formal' seed-supply systems, characterized by specialized organizations dealing with breeding and distribution of tested and approved varieties, applying strict quality controls (Almekinders and Louwaars, 1994).

Farmers in developing countries often have limited access to seed from formal seed-supply systems, which inhibits the adoption of new seed with the potential to out-perform the materials they have in their fields (Indimuli, 2013; Almekinders, 2017). This lack of access to formal seed supplies is partly attributed to a poor understanding of the dynamics of the (informal) seed systems on which farmers rely for their seed sourcing (e.g., Almekinders and Louwaars, 1994). Several authors (Cromwell et al., 1990; Almekinders and Louwaars, 1994; Louwaars and de Boef, 2012; McGuire and Sperling, 2015) advocated for improving the connections between formal and informal seed systems to increase farmers' access to planting materials. Almekinders and Louwaars (2002) argued that the formal seed sector should build upon, and be integrated with, existing informal (or farmers') seed systems rather than functioning in parallel to, and disconnected from, the informal sector. The first step in such integration is to understand farmers' motives and practices related to the sourcing and production of seed.

Some crop seed systems have been studied more intensively than others. Potato seed systems in the Andes and maize seed systems in Mesoamerica, for instance, have been extensively studied by both agronomists and social scientists (Keleman et al., 2009; Tomas-Sharma et al., 2015). The banana *(Musa sp.)* seed system in East Africa, by contrast, has been relatively little studied. Banana seed systems in East Africa are quite unique compared with other crops grown in the region: banana is perennial and vegetatively propagated. It has no 'seed' in the strict sense of the word but is generally multiplied by uprooting the suckers, offshoots that grow around the banana stem of the mother plant that can be replanted (Robinson, 1996). Moreover, East Africa has an enormous number of different banana cultivars. These factors have implications for the way farmers manage, choose and source planting material, as it is bulky, cannot be stored and is available in relatively low quantities.

It is known that smallholder farmers in Uganda, as in many other countries, mostly obtain banana suckers from 'informal' sources; farmers themselves multiply, select and distribute the suckers (Staver et al., 2010). In this way, they access planting material that is adapted to local agro-ecological conditions and socio-economic preferences, at a relatively low cost. At the same time, the diversity of cultivars grown by farmers contributes to the in-situ conservation of banana landraces. However, there are some disadvantages associated with seed sourcing through 'informal' seed systems: pests and diseases can easily build up and spread, reducing productivity and, at times, even threatening local food security, as happened with Banana Xanthomonas Wilt in East and Central Africa (Blomme et al., 2014). In addition, access to new or exotic cultivars with interesting traits is limited.

In this article, we present results of a seed system study conducted in Central Uganda, in which we studied how and why farmers maintain and value banana genetic diversity and their planting and seed-sourcing strategies, including seed selection and quality indicators. The emphasis of this study is on 1) exploring farmers' production objectives in relation to banana diversity; 2) understanding the demand for banana planting materials and how farmers share and diffuse these among themselves, and 3) gaining insights into farmers' evaluation of banana planting materials and the quality criteria

they use. We discuss the findings in the light of a fast-changing context: a changing climate, the emergence of new pests and diseases, increased integration in the market economy (Bellon, 1996; Rosenzweig et al., 2001; Morton, 2007; Rietveld et al., 2016) and threats to agro-biodiversity. We finish by proposing pathways to integrate formal seed sector initiatives into existing informal farmers' seed systems.

METHODS

Study area

The study was conducted in the Mukono district in Central Uganda, which borders the north of Lake Victoria and lies to the east of the capital city, Kampala. Mukono's climate is characterized by moderate temperatures, ranging between a mean annual minimum of 15ºC and maximum of 30ºC. Uganda has two rainy seasons - from March to May, and from October to December. Data were collected between September and December 2016 in five villages situated in two of Mukono's sub-counties, Ntenjeru and Nakisunga (Figure 1). The majority of the farmers in these two sub-counties are smallholder farmers although fishing, too, is an important livelihood activity in Ntenjeru sub-county. Banana is an important food and cash crop in both the sub-counties.

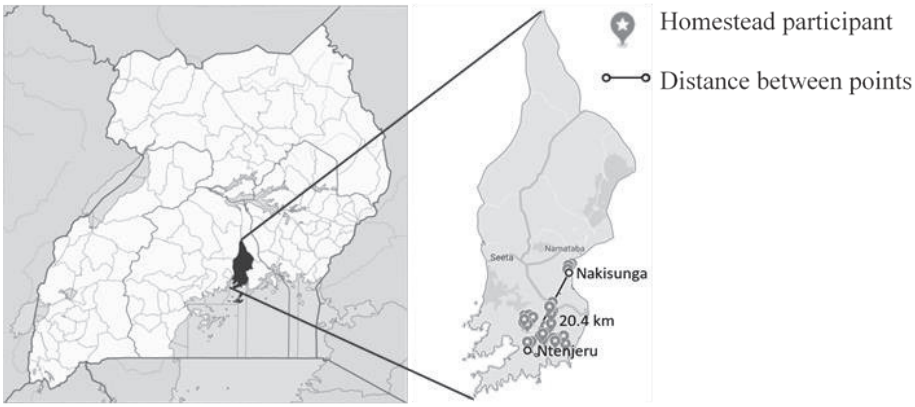


FIGURE 1. Map of Uganda showing Mukono district in black with a zoomed-in image of Mukono district showing the sub-counties Nakisunga and Ntnejeru and the locations of the farms where the 23 interviews were held. Sources: Adapted from Uganda Bureau of Statistics, 2017 and OpenStreetMap 2018.

Study design

The study was designed to explore different elements of the banana seed system, such as cultivar use, sourcing and evaluation practices of banana planting material, through use of Focus Group Discussions (FGDs) and semi-structured interviews. The information derived from using the two methods complemented each other. The FGDs were organized to generate a cultivar inventory through use of the four-square analysis (4 SqA) (Grum et al., 2008). The information was used to describe the diversity of banana cultivars and complemented the information on the different uses collected from the individual interviews. The individual interviews focused on agronomic practices and motivations of farmers. The data were partly processed quantitatively with descriptive statistics (e.g., Tables 1 to 6) and partly qualitative (e.g., descriptions of practices and observations, citations from farmers). The study adopted a gender-responsive design, whereby comparable numbers of men and women were included as study participants. To allow both men and women to participate comfortably and speak freely, the respondents were interviewed by someone of the same sex and participatory exercises were conducted in single-sex fashion. The data analysis was sex-disaggregated in order to bring out possible gender differences.

Four-square analysis

An adapted version of the four-square analysis (4SqA) (Grum et al., 2008) was used to collect information on the production and use of banana cultivars. Participants were first asked to list all cultivars grown in the area. Then, use, strengths and weaknesses, year of introduction and origin were discussed for every cultivar listed, after which they were each placed within a category in the 4SqA. Each category of the 4SqA represents the abundancy in which the cultivar is grown based on area and number of households. Four single-sex FGDs were carried out, two for both men and women but with different age-groups (18-40 years and 41-70 years). For logistical reasons, all FGD participants lived in Gonvé village in Ntenjeru sub-county (Figure 1). The participants were recruited by our local key informant in the village: a lady who had previously been involved in governmental and NGO banana programs in the village. She was asked to recruit male and female farmers of different ages, economic status and with varying amounts of areas

planted with bananas. The FGDs, held in October 2016, involved 6-8 participants and lasted for 2-3 hours.

Interviews and surveys

A total of 23 semi-structured interviews were conducted with individual male and female farmers from households of different wealth classes. Interviewees were selected purposefully by directly approaching people in the village and knocking on doors, with the aim of selecting a representative sample relative to socio-economic status and agro-ecological conditions. The interviewees were then characterized on basis of: type of house, livestock owned, farm type, size of banana plantation, sex and age. They were selected from Gonvé and four other villages, all situated in the sub counties of Ntenjeru and Nakisunga. There was little socio-economic and agro-ecological variation among the villages and the maximum distance between interviewed households was 20 km. By including farmers from a somewhat larger area, we wanted to increase the validity of our study, specifically in relation to identifying seed sources (farms, farmers) and flows. Each interview lasted 2-3 hours and followed the same protocol. First, we collected data on the farm and household, cultivation practices and input use, and then we discussed 'banana-specifics' while 'walking the farm'. During this walk, details, including cultivar name, age, origin and management information, were recorded for a maximum of 16 banana mats. Thus, data on sourcing of 279 individual banana mats were collected. The mats were selected as follows: Four mats of four cultivars from each farm were sampled, with, wherever possible, one cultivar fitting within each square of the 4SqA. The farmer was asked to first show us the oldest mat of the cultivar and end with the youngest. The last part of the interview addressed sucker management and farmers' perceptions of the desired qualities of planting materials.

Data analysis

The results of all four FGDs were combined to provide an overall picture of the uses and diversity of banana in the area. They were also compared to identify gender, age-group or wealth-specific differences. The farmers participating in the interviews were classified based on sex of the household head, age and wealth. Farmers aged 18 to 30 years were classified as young farmers, those between 31 and 50 years as middle-aged

and those aged over 50 as old. Wealth classification was constructed on basis of household assets and resources: type of house, the number of livestock and area of landholding (Table 1). The interview data were entered and coded in Excel and analyzed according to the frequencies of answers to identify trends and patterns. For some questions, numerical answers were given and these were analyzed using descriptive statistics (sums, means, standard deviation and ranges). The qualitative data were used to support and explain visible trends in the quantitative data

Table 1. Characterization of farmers in relation to their assets in housing, livestock and landholding.

Asset	Poor	Medium	Rich
Roof type	Grass – metal	metal	metal - roof tiles
Walls	Mud – brick	Brick	Brick - plaster
Floor	Earth – cement	Cement	Cement/tiles
Number of cows	0	1-5	>5
Number of pigs	<2	2-10	>10
Number of goats	<4	4-15	>15
Number of poultry	<5	5-20	>20
Area of landholding	<1.5 ha	1.5-5 ha	>5 ha

RESULTS

Household and cultivation characteristics

Of 10 women interviewed, six were heads of their household, which meant, de facto, that they were single and no adult male was living in the house (Table 2). The other 17 households were defined as male-headed by the interviewees, and four women respondents thus belonged to a male-headed household. All but one of the male respondents were married and living with their wives. The cultivated area under banana ranged from 0.1 to 2.4 hectare per household. On average, young farmers and single women had less area under bananas. The area under banana among poor households was also lower (median = 0.2 ha), with the exception of one farmer who cultivated 1.2 ha. He did not own the land but was allowed to farm on it by a wealthy man from Kampala. The mean area under bananas of wealthier households was about double that of the medium wealthy and poor households. The age of the banana plantation (calculated as

the number of years since establishment) ranged between 2 and 54 years, with a mean of 20 years. Younger farmers had younger banana plantations than older farmers.

All interviewees confirmed both men and women were involved in banana production. The majority of households intercropped bananas with coffee and/or legumes (beans). Households consumed approximately half of banana produce and sold the other half to local traders. In all households, banana was among the three most important crops for income generation. Inputs, such as manure, were mainly acquired from their own farm. The most common pesticide used was Rocket (Cypermethrin- a pyrethroid insecticide), which was applied by eight farmers against banana weevils.

Table 2. Characteristics of the group of interviewed participants (sex, age, wealth) in relation to their banana plantation (farm size and the mean year of establishment of the banana plot). Standard deviations are presented between brackets (SD).

Group	n	Men (n)	Women (n)	Age	Mean size banana plot in ha (SD)	Range	Mean age banana plot in years (SD)	Range
Sex of household head								
Male	17	13	4	48	0.73 (0.59)	0.1-2.4	20 (15)	2-46
Female	6	0	6	44	0.37 (0.28)	0.1-0.8	17 (19)	4-45
Age								
Old farmers	11	6	5	58	0.68 (0.40)	0.1-1.4	31 (14)	9-45
Middle aged farmers	7	4	3	44	0.77 (0.81)	0.1-2.4	13 (8)	2-25
Young farmers	5	3	2	27	0.36 (0.38)	0.1-1.0	4 (2)	2-7
Wealth								
Rich households	7	6	1	50	1.04 (0.73)	0.1-2.4	20 (17)	2-45
Medium households	11	6	5	47	0.43 (0.30)	0.1-1.0	19 (14)	2-46
Poor households	5	1	4	43	0.53 (0.46)	0.1-1.2	20 (20)	2-54
Total	23	13	10	47	0.64 (0.55)	0.1-2.4	20 (16)	2-54

Diversity of banana cultivars

FGD participants identified 30 different banana cultivars (Table 3) and 10 more cultivars were mentioned in the interviews. Interview respondents grew an average of 10 different banana cultivars on their farms and this was independent of respondents' sex, age or wealth status. Most cultivars (≈75 %) identified in the FGDs belonged to the endemic East African Highland Banana (EAHB) group, also known as Musa AAA-EA (Karamura, 2012). Cultivars belonging to each of the five major clonal sets in this group (Mbidde, Musakala, Nakitembe, Nfuuka and Nakabululu; see Karamura, 2012) were

grown. Participants also mentioned cultivars from more recently introduced genotypes, such as: Musa AAA groups, the Musa ABB group, plantains (AAB), apple bananas (AAB) and hybrid lines (FHIA). Table 3 contains a summary of FDG participants' responses in relation to 'the abundance of the cultivar in the community' and 'the year of introduction'. Answers on 'abundance' varied among the four FGDs: the most-frequently mentioned categories are shown in Table 3. Participants in the FGDs identified 22 indigenous and eight 'introduced' cultivars. Some cultivars identified as 'introduced' by the elder age-groups were not recognized as such by those in the 'youth' FGDs. This was, for instance, the case for the cultivars Kisansa and Kayinja, which are thought to have been introduced 40-50 years ago. Several more recently introduced cultivars, such as Lwadunga and AGT, were only mentioned in the youth FGDs. Three different sources of the introduced cultivars were identified: two government agencies; the National Agricultural Research Organization (NARO) and The National Agricultural Advisory Services (NAADS) and a private-sector company, Agro Genetic Technologies Ltd (AGT). Half of the cultivars listed and categorized in square 1 of the abundance analysis (grown by many farmers on a large area) consisted of introduced cultivars. These cultivars (such as Mpologama and Kisansa) were appreciated for their big bunches and high yields.

Each of the cultivars mentioned had one or more main use(s): brewing, cooking, roasting or dessert bananas. Cooking and dessert cultivars were represented in squares 1, 2 and 4, but brewing and roasting type cultivars were only placed in square 4 'grown by a few farmers on a small area'. None of the cultivars was consistently placed in square 3 'grown by a few farmers on a large area'; only the young women placed the cultivars Mpologoma and Kisansa in square 3. They pointed out that some varieties could be represented in more than one square because they were grown by large-scale farmers in large quantities but could sporadically be found on the farms of small-scale farmers as well. Some cultivars were identified by farmers as extinct or nearly extinct in the area. Mostly the production of brewing cultivars, such as Kisubi, Kayinja or Mbidde, had declined in recent years, mainly as a result of high susceptibility to Banana Xanthomonas Wilt (BXW).

Table 3. Four square analysis of banana cultivars and their abundance, type and year of introduction estimated by farmers in Gonvé village. Cultivars with a symbol are recognized as introduced by different groups.

Square 1. Many farmers – Large area

Local cultivar name	Type	Introduction
Bogoya	Dessert	Indigenous
Tombadala	Dessert	2006
Kibuzi	Cooking	Indigenous
Kisansa ‡¶	Cooking	1970
Mpologoma † ‡ § ¶	Cooking	2000
Nakitembe	Cooking	Indigenous

Square 2. Many farmers – Small area

Local cultivar name	Type	Introduction
FHIA † ‡ § ¶	All	1998
Kibuzi black	Cooking	Indigenous
Kivuvu	Cooking	Indigenous
Musakala	Cooking	Indigenous
Muvubo	Cooking	Indigenous
Ndiizi	Dessert	Indigenous

Square 3. Few farmers – Large area

Local cultivar name	Type	Introduction

Square 4. Few farmers – Small area

Local cultivar name	Type	Introduction
AGT †	Cooking	2004
Bogoya red	Dessert	Indigenous
Gonja	Roasting	Indigenous
Kayinja ‡¶	Beer	1970
Kisubi	Beer	Indigenous
Luwaata	Cooking	Indigenous
Lwandungu †	Cooking	2011
Mbidde	Beer	Indigenous
Mwazirume	Cooking	Indigenous
Nakabululu	Cooking	Indigenous
Nakawere	Cooking	Indigenous
Nakytengu	Cooking	Indigenous
Nambi	Cooking	Indigenous
Namwezi	Cooking	Indigenous
Nandigobe	Cooking	Indigenous
Nsalwagiri	Cooking	Indigenous
Nfuuka	Cooking	Indigenous
Ndiizi Mfungu †	Dessert	1998

† Cultivar is recognized as introduced by young men
‡ Cultivar is recognized as introduced by older men
§ Cultivar is recognized as introduced by young women
¶ Cultivar is recognized as introduced by older women

Use and socio-cultural significance of banana cultivars

The classification of bananas into cooking, dessert, roasting and beer types only indicates the main use of the banana bunch. Other parts of the banana plant are also used; the pseudo stem is used as animal fodder, packaging and mulch, and its fibres are used to make fire, ropes, mats and baskets. Banana leaves are used for mulching, for packaging and in food preparation when food is steamed. The participants often mentioned this last use of leaves as important. Not all cultivars produce suitable leaves for steaming food. Bogoya and Ndiizi were mentioned as having good leaves for

steaming as they gave the food a nice aroma and a yellow color. Some cultivars are valued for their medicinal properties; Gonja is used to hasten the healing of new-born babies' navels and Mbidde to prevent vomiting. Bananas are also associated with many cultural traditions, ceremonies and rituals. It is traditional to bring a banana bunch (or several if you are wealthy) to social gatherings, such as weddings, and to drink banana-beer. When a baby-girl is born, the placenta is buried under a mat of Nakitembe and a baby-boy's placenta under a mat of Mbidde or Kayinja. The placenta is viewed as a twin of the new born baby and requires a respectful burial. The practices of cultivation are also subject to traditional rules and beliefs: the plantation is almost considered a living organism, which requires respect. As one female respondent said:

> *"Because the banana plantation knows me, I am the only person uprooting suckers from my plantation. If I were to allow fellow farmers to uproot in my garden, I might anger my plantation. Whenever I want to uproot suckers, I first inform my plantation I am going to take some of her children away. I do so by cutting off the tops of a few suckers the night before I want to uproot. It is a kind of 'death announcement' that I make to the plantation before taking the children away."*

Cultivars are generally also arranged in specific patterns within the plantation. Food cultivars are traditionally grown in mixtures. There should be at least one mat of Mbidde (beer banana) in the middle of the plantation as this cultivar represents "the man of the plantation". Some cultivars, considered to be 'bad neighbors' to other cultivars, are planted at the edges of the plantation, such as Bogoya, Ndiizi and Gonja. Gonja is also placed at the boundaries, as it is said to protect the plantation against thieves. Some farmers grow dessert and brewing cultivars on remote fields in more extensive management styles.

Banana suckers and the replacement dynamics of banana mats

Bananas are tree-like perennial herbs that do not have a fixed lifespan (Robinson, 1996). Farmers estimated the lifespan of banana mats to vary from five years for the Nandigobe and Mpologoma cultivars (Both EAHB-AAA) to 83 years for the Bogogya cultivar (AAA). However, many farmers claim that, under the right conditions and management, a banana mat can live forever as new suckers keep regenerating, which is referred to by

the farmers as the mats 'continuity'. Disease infestation, unfavorable climate conditions or poor management can cause a banana mat to decline in productivity or die. Declines in the productivity of banana mats are generally attributed to 'the age of the mat', 'pests and diseases', 'competition from other banana mats' or 'declining soil fertility'. One male farmer explained that the soil has a great influence on a mat's productive lifespan:

> *"Bananas are very soil selective and that is why different cultivars are preferred in each area and their lifespans vary. I take the soil type into account on my farm. Through trial and error, I have come to understand my soil and know which cultivars thrive well in which parts of my farm."*

Low-performing mats can be replaced by uprooting them and replacing them with a new sucker. Similarly, a new sucker can be planted in the gaps left by a mat that has died or created by the movement of mats . Because of the practice of mixing different cultivars in the plantation, the differences in strengths and weaknesses of the cultivars and the high on-farm diversity of cultivars used, it is very rare that large areas of banana mats show a decline in productivity or die at the same time. Thus, the plantations are kept vital in two ways: 1) by managing an existing mat in such a way that it keeps regenerating and 2) by planting banana suckers to fill gaps in the plantation, or replacing unproductive mats (Figure 2). Farmers follow different strategies when gap-filling and replacing banana mats. Some actively uproot mats showing a decline in productivity and replace them with a new sucker, whereas other farmers only fill gaps that occur naturally through the death or movement of a mat. This decision mainly relates to the farmer's ability and willingness to invest labor, as uprooting a banana mat is labor-intensive. For this reason, female farmers and older male farmers in our sample tended not to uproot and replace low productive mats. When the research team pointed out to one of the female farmers that she had a mat infected with BXW on her farm she replied: "I am too tired to uproot these diseased mats and the disease keeps coming back anyway". Gender norms, which prescribe uprooting as 'men's work', might also play a role in women's consideration not to uproot (Rietveld, 2017).

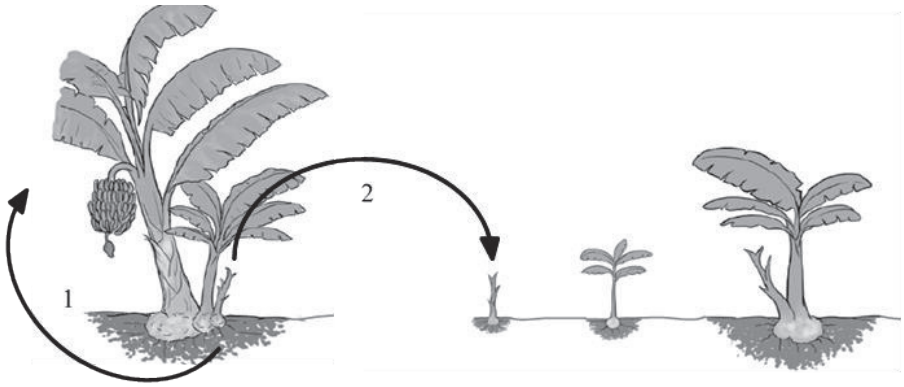


FIGURE 2. Two ways to maintain the vitality of a banana plantation. 1: Under favorable circumstances and proper management a banana mat continuously produces new suckers. These suckers will follow up on the mother plant after a bunch has been harvested. 2: A new banana mat can be established by uprooting a sucker from the mat and planting it elsewhere. The sucker will eventually grow into a new banana mat. Source: Adapted of Wairegi et al., 2016.

The need for suckers and how farmers source them

Since farmers only plant a whole area when they are expanding or establishing a plantation, gap-filling tends to be more common. This has consequences for the need for suckers or planting material. Gap-filling tends to happen in a haphazard fashion, whenever a gap occurs, suckers are available and the soil is humid enough. Most farmers could not recall the exact number of suckers they planted during the previous rainy season (the April rains of 2016). Many farmers said they had faced a shortage of suckers on their farms because of prolonged droughts in the 2015-2016 planting seasons. On average, farmers estimated having planted 19 suckers, i.e., 52 suckers per hectare during the April planting season. The number of suckers available for planting from their own plantation was estimated at 5 to 300 by the farmers, which translates to a mean of 189 suckers / hectare (Table 4). Farmers considered a sucker to be 'available for planting' when it was not needed for the continuity of the mat from which it was to be extracted and when it was of sufficiently good quality. More details about farmers' perceptions of sucker quality are described in the next section. Young farmers generally had more suckers available than older farmers. Farmers estimated that they needed 70% of their available suckers for filling gaps and replacing mats in the coming season, but this figure varied widely among them. About half of the farmers needed 100% of their own

available suckers for replanting, whereas one young farmer expected not needing any suckers in the coming season.

Table 4. Estimated number of suckers available per ha, the % of those suckers farmers expect they will need for the coming planting season and the estimated number of suckers planted per hectare, classified by different social groups. Standard deviations are presented between brackets (SD).

Group	n	area (ha)	No. of suckers planted	Range	No. suckers available /ha†	Range	% suckers needed on farm†	Range
Male-headed households	17	0.7	38 (42)	0-124	147 (157)	12-519	72% (34%)	0% -100%
Female-headed households	6	0.4	67 (137)	3-346	266 (242)	16-692	67% (29%)	33%-100%
Old farmers	11	0.7	17 (31)	0-109	72 (77)	12-177	87% (24%)	40%-100%
Middle-aged farmers	7	0.8	79 (120)	5-346	181 (128)	41-371	71% (29%)	33%-100%
Young farmers	5	0.4	63 (52)	10-124	381 (285)	49-692	43% (31%)	0% -71%
Rich households	7	1.1	22 (35)	0-99	107 (100)	19-247	80% (28%)	40%-100%
Medium wealthy HH's	11	0.4	76 (99)	0-346	208 (170)	12-518	67% (38%)	0% -100%
Poor households	5	0.5	13 (7)	5-25	244 (288)	16-692	65% (28%)	33%-100%
Total	23	0.6	46 (76)	0-346	189 (193)	12-692	70% (31%)	0% -100%

†The sample size for these questions was smaller since it was not included in the first five pilot interviews (n=17), see Table 6 for n per group.

Seed sourcing practices

Of the 279 sampled banana mats, 59% originated from suckers from existing banana mats on the farmers' own farms. Sometimes the banana mats were already in place when the farmers obtained rights to the land / banana plantation (referred to as 'inherited' in Figure 3). Farmers also sourced planting material from friends, relatives and neighbors. Seventy percent of the mats sourced off-farm were a gift, the remainder 30% included a monetary transaction ranging between 500 and 1500 UGX (≈US$ 0.15-0.40). Only 14 mats (circa 5%) had been sourced from the formal seed system, mostly via NAADS, the government extension program.

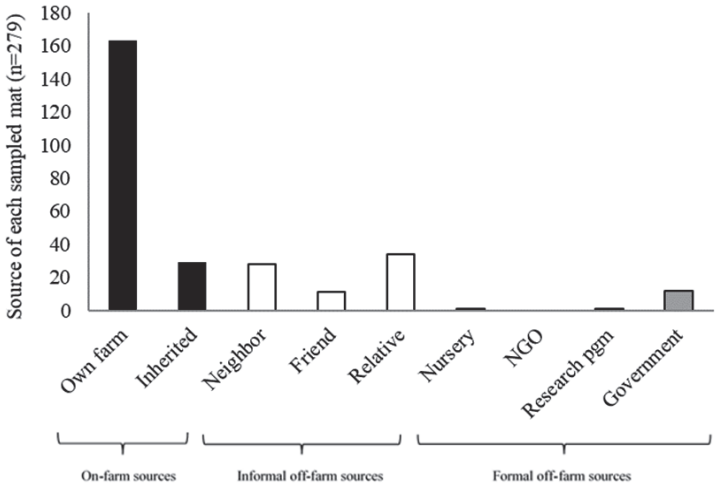


FIGURE 3. Source of each sampled mat (n=279). Black bars are on-farm sources, white bars informal off-farm sources and grey bars formal off-farm sources.

All farmers preferred to source suckers from existing mats on their own farm because they were familiar with these plants and could thus predict performance, properties and pest and disease status of the sucker. There were three main reasons why farmers sourced suckers from elsewhere: 1) insufficient suckers available on their own farm; 2) interest in other cultivars, and; 3) seeing high performing bananas (bearing big bunches) on someone else's land. When sourcing from their own farm, farmers selected suckers on the basis of the condition of the mat, the mother plant and the sucker itself. When sourcing from elsewhere it is often not possible to see the mat or mother plant as the suckers are usually uprooted and sometimes even pared by the source-farmer. Farmers thus miss reliable information (other than the source-farmer's testimony) about the sucker and even might not be sure which cultivar they are sourcing. Sometimes source-farmers would allow a receiving farmer to select suckers in their plantation but generally only if they were close relatives or friends or when a monetary payment was involved. Decisions on where, or from whom, to source suckers were based on multiple criteria, such as the presence of pests and diseases, the management of the source-farmer and types of cultivars grown on the farm (Table 5).

Table 5. Criteria of farmers in their decision for an off-farm source and number of farmers naming each criteria (n=23).

What do you take into consideration when choosing an off-farm source?	n†
The presence of pests and diseases on the farm	15
The way a the farm is managed and if the farm is in a good condition	9
The bunch sizes on the banana mats on the farm	8
The types of cultivars that are grown on the farm and how they would perform on my own farm	4
The reputation of the farmer	4
The age of the plantation	1
Total	41

† Farmers could mention more than one criterium

About half of the farmers claimed having a surplus of available suckers on-farm and thus the ability to provide suckers to others. Only a minority of 8 out of 23 farmers had shared suckers in the last rainy season and the maximum number of suckers shared per farmer was 200. The mean number of suckers shared per ha for only those farmers that actually shared suckers it was 76 per ha. Old farmers were less likely to share, and shared fewer suckers than other groups. Although both men and women from all wealth statuses claimed to share suckers, several poor farmers said they never received suckers from fellow farmers. One of the poor female heads of household explained: *"I do not receive suckers from fellow farmers because I cannot share or sell suckers myself. If someone came to me now to ask for suckers, I would not even have one available. People around here only want to sell suckers to me for 1000 UGX (≈ 0.30$)".*

Farmers' perceptions of the quality of banana suckers

Farmers assess the quality of a sucker destined for planting before they uproot it, on the basis of a range of traits of the mat, the mother plant and the sucker itself (Table 6). The traits most frequently mentioned related to the sucker itself, viz., leaf shape and size, pseudo-stem shape, sucker size and weevil damage. Leaf shape and size, pseudo-stem shape and sucker size indicate age and nature of the sucker and determine if a sucker is a 'sword' or 'water' sucker. The distinction between these two types of suckers can therefore be considered the main criterion for farmers, who prefer sword suckers and dislike water suckers, often referring to them as 'abnormalities'. Water suckers are young suckers with a thin, straight pseudo-stem that have developed big and broad leaves. One of the farmers described them as follows: "They are like a 4-year old boy

with a beard, if you saw a boy like that you would just know that something is wrong inside". Sword suckers, by contrast, have a cone-shaped pseudo-stem with a broad base and spear-shaped leaves. The number of water suckers generally increases with the age of the mats, as they become shallower, which results in a smaller connection between the mother corm and the sucker (Robinson, 1996). This might explain why older farmers seemed to have fewer available suckers (Table 5).

Table 6. Characteristics taken into account while selecting a sucker and the number of farmers naming each characteristic (n=23).

Category	Characteristic	n†
Sucker	Leaf shape and size	14
	Shape of the pseudo stem	13
	Size of the sucker; Weevils and/or boreholes in corm/stem	9
	Color of the leaves	6
	Health of the sucker	5
	Color pseudo stem	4
	Position of leaves along the pseudo stem; Number of leaves	2
	"Ash" on the base of the leaves; Cigar leaf coming up vertically; Reddish color on the base of the leaves; Depth of the roots; Color of corm after paring	1
Mat	Continuity (number of mother plants, followers/children, and suckers/ grandchildren on the mat)	5
	Age of the mat	2
	Place on the mat where sucker appears; Distance between the sucker and the mother plant; Corm of mat above soil surface or not	1
Mother plant	Bunch size given by mother plant	6
	Weevil infection of mother plant	5
	Health of mother plant	4
	Diameter pseudo stem of mother plant	2
	Size of fingers of mother plant	1

† Farmers could mention more than one trait.

The mat trait most frequently mentioned by farmers was the regeneration or continuity of the mat, referring to the number of growth cycles a mat has been through. Farmers can enhance the continuity of the mat by leaving the 'right' number of suckers on the mat. They explain that removing too many suckers weakens the mat and drives it to an early death. On the other hand, leaving too many suckers on the mat can reduce productivity, as the suckers draw on the available carbohydrates. 'De-suckering' is

therefore a common management practice (Robinson and Nel, 1990). Judging the 'right' number of suckers to be left on the mat depends on the farmers' management style and on the cultivar. Most farmers compared the plants on one mat to a family; the oldest plant on the mat, which produces a bunch first, is referred to as the mother, the second-largest or eldest plant is called the daughter and the suckers following that are the grand-children. According to those farmers, a mat needs a mother plant, one daughter and at least two vital grand-children (suckers). This often means that the best suckers are kept on the mat to ensure its continuity, and are not available for replanting. The implication is, for an optimal management regime, at least four vital suckers should be present on the mat before it can be considered ready to provide any planting materials.

Not all farmers named the same number of traits for selecting a sucker, nor did all farmers take the mat and mother plant into account. This was sometimes not necessarily attributable to a lack of knowledge but, rather, out of necessity, as healthy, vital suckers can be scarce. One woman, head of a poor household, explained:

> *"I know there are more characteristics to look at while selecting a sucker, but I do not take those into account. None of my suckers would pass those criteria anyway so why should I use them? For me it is most important that the suckers are free of diseases, if they are, I plant them."*

DISCUSSION

Farmers in Mukono district maintain high on-farm banana cultivar diversity because of the multiple end uses of the different cultivars but also because the diversity in strength and weaknesses reduces production risks. Low-yielding cultivars can be retained because of other superior traits, such as good taste or because they have a certain cultural value. Farmers have adopted newly introduced, higher yielding cultivars, such as FHIA and Mpologoma, by integrating them in their portfolio of cultivars. This process of testing and adding banana cultivars, rather than displacing them, has been described earlier by Gold et al. (2002). The introduction of new, potentially superior banana cultivars can threaten agro-biodiversity and in situ conservation of traditional cultivars (Tripp, 1996), as has happened with maize, rice and wheat (Keleman et al., 2009;

Chaudhary et al., 2004; Tsegaye and Berg, 2007). In Mexico, the loss of diversity of maize has been attributed to the reduced relevance of specific end-uses (Keleman et al., 2009). Since multiple end uses of bananas are a key driver for maintaining diversity, similar genetic erosion might occur among Ugandan banana farmers if their needs or production objectives change. For instance, as farmers become increasingly linked to the cash economy and markets, productivity can become the primary objective and other end-uses (e.g., steaming, medicine, packaging) become of less relevance since products, such as plastic and pharmaceuticals, can be accessed elsewhere.

Another reason why newly introduced cultivars, even when considered by farmers as superior, might not be adopted on a large scale in a short timeframe, can be found in banana's unique replacement dynamics. Farmers normally aim to extend the lifespan of their banana mats, which means that a proportion of the good quality suckers remain on the mat and that there are relatively few good suckers potentially available for planting and exchange. In addition, most farms have a mixture of banana cultivars and therefore a substantial number of suckers of a single cultivar is rarely available. Climate variation can also influence sucker availability. For example, the previous growing season had been exceptionally dry, and farmers had insufficient sucker supplies.

Large amounts of planting material are usually only required when a new farm is established or when the farm is expanded. Once a banana plot is established, farmers prefer to fill gaps in the plantation that occur because the banana mats die or move, rather than re-planting the whole plot. This, in combination with several factors, makes the demand for planting material highly irregular and difficult to predict. These factors include: the perennial nature of bananas, the high on-farm diversity of cultivars, differences in strengths and weaknesses of cultivars, and the differences in mat replacement management among farmers. Although planting material from farmers' own farms is preferred for gap filling, farmers also source suckers off-farm if they need more suckers than are available on their own farm, or when they want to add a new cultivar. When doing so, farmers holistically evaluate the sucker, the mother plant, the mat, the farm, and the management of the source farmer. This means that farmers (irrespective of gender, age or wealth status) prefer to source planting materials from

within their own social networks. Exchange of planting material is often mentioned as a common route for pest and disease transfer (Tenkouano et al., 2006, Staver et al., 2010; Kikulwe, 2016). However, the relatively low frequency of planting material exchange, in combination with a holistic approach of quality evaluation, makes it less likely that all pests and diseases are transferred on a large scale via exchange of planting material. It is plausible that other ways of disease transfer, such as insect transmission and the exchange of tools, are responsible for fast spread of some pests and diseases. Therefore, the fact that some farmers are unable or reluctant to uproot diseased mats might pose a large risk to disease spread because they form a source of infection for surrounding farms. Keeping the banana mats small by de-suckering could facilitate removal of diseased mats, as it requires less physical strength. Further research on pest and disease transfer could clarify if this assumption is true and thereby improve strategies to reduce spread of pests and diseases.

Some farmers pointed out that limited availability of quality planting materials from their own farms and social networks forces them to use sub-standard planting material. Social networks have proven to provide quite a successful mechanism for distributing improved varieties of seeds of several crops, such as wheat, rice, beans and potato (Cromwell et al., 1990; Dorward et al., 2007; Ronner et al., 2016; Tadesse et al., 2016). This suggests that it is important to study and understand flow of planting materials through social networks. Seed-system studies have also highlighted that wealthy farmers are more likely to act as a source of planting materials than poorer farmers (Sperling and Loevinsohn 1993; Subedi et al., 2003; Tadesse et al., 2016) as they are more likely to have surplus planting material, whereas poor farmers are more likely to have chronic shortages (McGuire, 2008). Our study found that men and women of all wealth classes provided suckers to fellow farmers. While there were differences in sucker availability, our limited sample size was insufficient to determine if, and the extent to which, gender and wealth status (or other social factors) play a role in determining on-farm seed surpluses or shortages. As explained earlier, there are several reasons why both sucker availability and demand are very variable between planting seasons. Therefore, our 'one-season snapshot' is insufficient to identify which farmers function as a seed-source or to understand the rules that guide seed exchange. To address this, and the mechanisms

that underpin the exchange of planting materials, more comprehensive research would be needed across multiple planting seasons.

CONCLUSIONS AND RECOMMENDATIONS

Increasing farmers' access to high quality, clean seed of preferred cultivars is an important way of improving banana productivity and profitability. Yet, high on-farm genetic diversity, differences in the lifespan of banana mats, the variability in replacement dynamics among different types of farmers and the difficulty in storing banana suckers, make it extremely challenging to design and run interventions that effectively enhance banana productivity.

Interventions geared towards improving banana seed systems in Central Uganda need to adopt a long-term perspective and recognize the imperative of patience. The perennial nature of banana, the cultural preference for the longevity of plantations and the multiple end uses to which bananas are put, coupled with the large labor investment required in uprooting existing mats, mean that the adoption of new cultivars progresses slowly. Development initiatives should be wary of defining 'success' as the large-scale replacement of landraces with new cultivars. Not only do data suggest that farmers value high on-farm diversity for multiple reasons, but the in situ conservation of banana cultivars is valuable in itself and is beneficial for the formal seed sector in the long run (as a reservoir of genes/traits).

The diversity of banana cultivars in central Uganda is maintained by a variety of mechanisms. Social ones, such as food and nutritional security, and multiple consumption, functional and cultural uses, play a key role, as do biological ones: the multiplication of bananas via suckers, and the difficulty in storing them, does not allow for large quantities of a similar cultivar to be available at any given time. The introduction of new and faster multiplication methods, such as tissue culture, could provide large quantities of a single cultivar and thus increase access to new and clean planting material but at the same time could narrow the number f cultivars grown. Moreover, because of farmers' preferences for maintaining diverse plantations and their

holistic way of assessing quality (mainly based on trust within social networks), farmers might well be hesitant to adopt these new types of planting material. Interventions will have to offer convincing arguments or strategies to interest farmers in paying for planting materials that look very different than those they are used to and will not only have to prove that their materials are 'superior' but also teach farmers how to assess and manage the new material and build up a relationship of trust.

CHAPTER
Four

Not only the seed matters: Farmers' perceptions of sources for banana planting materials in Uganda.

Publication information

Adapted version of: Kilwinger F, Marimo P, Rietveld A, Almekinders C and van Dam Y. (2020). Not only the seed matters: Farmers' perceptions of sources for banana planting materials in Uganda. Outlook on Agriculture, 49(2), 119-132.

ABSTRACT

The adoption of improved seed and other planting material in developing countries shows mixed results despite their potential to increase agricultural productivity. To arrive at a better understanding of the observed adoption rates, a lot of research is focused on finding the cultivars and variety traits that are attractive to farmers. Given smallholder farmers' seed-sourcing practices are often influenced by social ties and cultural norms, it is also relevant to understand where and why farmers seek to acquire planting material. In this study, means-end chain analysis was applied to understand farmers' perceptions of formal and informal sources of banana planting material. Means-end chain analysis allows respondents to select and verbalize their own constructs to evaluate a product or service. These personally relevant constructs are subsequently linked to their personal goals via laddering interviews. We interviewed 31 Ugandan banana farmers from Western and Central region. Farmers associated formal sources mainly with improved cultivars, tissue culture plantlets and low levels of diversity. Informal seed sources were mostly associated with traditional cultivars, suckers and high levels of diversity. The goals farmers pursued while acquiring planting material, such as financial gains, food security, and to sustain and develop the household, were fairly similar among different groups of farmers. The means through which farmers aimed and preferred to pursue these goals differed and could be related to aspects such as gender, production scale and production goals. These differences among farmers preferences for particular sources indicate that not only cultivar traits should be tailored to farmers' preferences and needs, but also the characteristics of the sources from which farmers access planting material.

INTRODUCTION

Improved agricultural technologies promoted by governments and other actors are not necessarily adopted by farmers, particularly in developing countries (Almekinders et al., 2019b; Walker and Alwang, 2015). This might be explained by a lack of information and understanding on farmers' preferences and priorities and the way the improved technologies fit their realities (Almekinders et al., 2019b). In line with this, it is argued that agricultural innovations should not be viewed as stand-alone technological improvements but rather as elements of an agricultural innovation system which includes social elements as well (Klerkx et al., 2012). An improved agricultural technology might be considered beneficial because of its potential to increase yield, but the real-life outcome of adopting the technology by farmers might be variable due to nontechnological elements, such as culture, personal preferences, and institutional arrangements.

Many technology development efforts in agriculture deal with the improvement of planting material, particularly in the form of breeding improved cultivars and improving propagation methods. However, much less research goes into understanding how technologies, i.e. seeds (true seeds and other propagation materials1) of improved cultivars, can be accessed and how this differs between farmers. Evaluating the sources and delivery channels of planting material of vegetative propagated crops such as potato, cassava or banana is especially important because the material is usually bulky, highly perishable, difficult to store, has low production rates compared to "true seed crops," and is prone to easy build-up of pathogens that affect seed health (Bentley et al., 2018).

In developing countries, informal (local, traditional, farmer) seed systems are the dominant sources of planting material for vegetatively propagated crops (Almekinders et al., 2019a; Andrade-Piedra et al., 2016). Seed exchange among farmers is usually strongly influenced by social ties and cultural norms, rarely involves monetary transactions, and provides farmers with planting material of cultivars adapted to their agro-ecological and socioeconomic conditions (e.g., Adam et al., 2018; Kilwinger et al., 2019a; McGuire, 2008, Tadesse et al., 2017; Van Niekerk and Wynberg, 2017).

Formal seed systems, in contrast, are characterized by the production and distribution of tested seed and registered improved cultivars, following strict quality control measures (Almekinders et al., 1994).

On-farm seed multiplication and exchange can result in the build-up and transfer of diseases (e.g., Andrade-Piedra et al., 2016; Jacobsen et al., 2019; Thomas-Sharma et al., 2016). For example, the spread of Banana Xanthomonas Wilt (BXW) in Uganda has partially been attributed to exchange of infected planting material among farmers (Blomme et al., 2014; Karamura et al., 2008; Kubiriba and Tushemereirwe, 2014). In some regions of Uganda where highly susceptible cultivars dominated, the rapid spread of BXW wiped out entire banana groves (Rietveld et al., 2014; Tinzaara et al., 2013). To prevent these kinds of disasters, numerous seed system interventions aim at providing farmers with clean and disease resistant planting material. This is usually done by establishing and strengthening the formal seed system.

One of the larger recent interventions in the banana seed system in Uganda was the Tissue Culture (TC) program by, among others, the National Agricultural Research Organization (NARO), Bioversity International and the International Institute of Tropical Agriculture (IITA) (Kikulwe, 2016). This project aimed to make TC banana plantlets available to farmers via improved market pathways, private partnerships and improved institutional policies. Considerable effort went into the establishment of demonstration trials and nurseries to familiarize farmers with the use of TC banana plantlets; normally farmers plant banana suckers (e.g. Kilwinger et al., 2019b). Research findings demonstrated the superior performance and profitability of TC plantlets over regular banana suckers (e.g., Kabunga et al., 2012a; Kikulwe, 2016). The plausible reaction from farmers following such initiatives would be adoption, but despite efforts and the presumed benefits, use of TC plantlets among Ugandan farmers remained relatively low. Sales of TC plantlets at nurseries dropped seriously after the project ended and some nursery owners even mentioned a decline in sales of up to 70% (Kilwinger et al., 2017). The explanation for such a situation tends to be found in the performance of the materials being supplied (e.g. Kabunga et al., 2012a), economic factors hindering adoption (e.g. Murongo et al., 2019; Muyanga, 2009) and other

technology-acceptance factors (Mulugo et al., 2019). The type and characteristics of the source or provider of the materials is usually not considered.

Formal sources, as compared to informal sources, may not only offer different cultivars and types of planting material but also the procedure of acquiring the material is likely to be different. Unlike informal sources, formal sources often involve transport costs, (higher) cash requirements, and no social relation is developed between the buyer and seller. Little is known about how such differences in the seed sourcing procedure influence farmers' decision and choice for a particular seed source. It is therefore important to isolate beneficial from inconvenient differences as well as to assess the effect of these differences. In addition, it is relevant to understand how these benefits and inconveniences play out for different types of farmers: characteristics of the household or farmer like sex, level of education and farming experience, as well as household farm size, income, and the relative importance of banana production as compared to other livelihood activities can play a role in determining seed needs, preferences and purchasing power. If, for example, formal sources have large volumes of planting material available, this might be a beneficial characteristic for large-scale farmers but irrelevant for small-scale and subsistence farmers who often require smaller quantities.

In this paper, we apply the means-end chain analysis to understand how farmers perceive banana planting material from different sources including private sector companies, public organizations, nongovernmental organizations, and local sources such as neighbors and the own farm. The means-end chain analysis was developed in the 1980s to understand how consumers evaluate, and why consumers value the products or services they purchase (Grunert and Grunert, 1995; Gutman, 1982). The method acknowledges individual differences in experiencing reality by allowing respondents to select and verbalize their own constructs by which their reality is linked to their personal goals (Reynolds and Gutman, 1988; Walker and Olson, 1991). This makes means-end chain analysis a valuable tool for crosscultural and cross-subcultural studies (e.g., Barrena et al., 2015; Valette-Florence, 1998). Recently, the means-end chain method has been used to understand farmers' perceptions of agricultural

technologies and practices (e.g. Hansson and Lagerkvist, 2015; Ngigi et al., 2018; Okello et al., 2018; Tey et al., 2015; Urrea-Hernandez et al., 2016). In this study we further explore the usefulness of this method for the identification of delivery conditions of banana planting material that are attractive to farmers.

METHODS

Study areas

The study was conducted in two districts in Uganda: Mukono in the central region and Mbarara in the western region of the country. The districts were chosen based on differences in cultivation history, intensity of banana production and level of activity of formal seed system actors. In Central Uganda, banana is a traditional crop which has been cultivated for hundreds of years (Rietveld and Farnworth, 2018). Due to diseases, low soil fertility and labor constraints, production in Central Uganda declined over the last three decennia and shifted to western parts of the country were banana cultivation is relatively new (Bagamba et al., 2010, Gold et al., 1999). As a result, banana production in Western Uganda is more intensive and commercial whereas in Central Uganda, production goals are more focused towards home consumption and traditional uses (Kilwinger et al., 2019a). According to the 2009/10 agricultural census report (UBOS, 2010), the western region had the largest production of cooking banana (68%) followed by the central region (23%). The promotion of improved planting material by nongovernmental organizations (NGOs) and government institutes was more intense in selected areas of the Mukono district in Central Uganda as compared to Mbarara district in Western Uganda. The promotion of TC banana also started in the central region of Uganda in 2008 (Kikulwe, 2016).

Study design

Farmers from the study sites in Central and Western Uganda were selected via quota sampling. The research team moved around in the chosen villages to encounter sufficient farmers willing to participate while keeping in mind the need to select a diverse group of respondents in terms of sex, age and farm size. In total, 32 farmers—

16 from each district—participated in the means-end chain analysis. In Mbarara district, one interview could not be completed, hence it was dropped from analysis. Demographic information on age, sex, total farm size and area under banana production was collected from each respondent. In addition, farmers were asked about general aspects of their banana production, the seed sources and cultivars they used, and whether they had been beneficiaries of banana seed system interventions. Farm households that estimated that they cultivated banana on an area larger than 1.6 ha were classified as large-scale farmers. Prior to data collection, five enumerators, three men and two women, had received a 2-day training on the interview technique.

After collecting the demographic and banana production characteristics of the household, means-end chain interviews were conducted. The interviews consisted of two parts: attribute elicitation and laddering. The elicitation technique we used was triadic sorting based on Kelly's repertory grid. In this technique, the respondent is presented with consecutive triplets of three fairly similar products or services which have to be sorted according to similarities and differences perceived by the respondent (Kelly, 1955). In our study, farmers were presented with triplets of cards which had sources for banana planting material written on them in the local language. In total, farmers were presented with nine cards each with a different seed source, including five formal and four informal sources. The sources were a laboratory, a nursery, the National Agricultural Advisory Services (NAADS), the National Agricultural Research Organization (NARO), a nongovernmental organization (NGO), a large-scale farmer, a remote farmer, a neighbor and own farm (Table 1).

When all seed sources were discussed with the farmer, (s)he was presented with nine predefined triplets of cards (full data presentation underlying the reported results in this article are available in Kilwinger et al., 2020a). In case a farmer was not familiar with a particular source, all the sets including that particular source were removed. Each time the farmers were presented with a triplet of cards they were asked to group two sources which, according to them, appeared to be more similar as opposed to t other. While doing so the farmers were given the following scenario:

"Imagine you have to source banana planting material for the coming planting season. I now present you with three seed sources where you could source this planting material. Which two seed sources have, according to you, more similarities as opposed to the other?"

Table 1 Brief description of the nine seed sources for banana planting material used in the study.

	Source	Description
Formal	Laboratory	A laboratory producing tissue culture (TC) banana plantlets. Tissue culture plantlets are produced in laboratories and can be distributed on behalf of other organizations and to nurseries, but can also directly be accessed by farmers (Kilwinger et al., 2017). Sourcing from a laboratory meant farmers directly acquired the planting material from the laboratory without any intermediate organisation or nursery.
	Nursery	A nursery for banana planting material. Several nurseries have been established as part of seed system interventions (Kikulwe, 2016). Nurseries usually provide TC plantlets but since most nurseries have a large mother garden, suckers can also be obtained.
	NAADS	The National Agricultural Advisory Services (NAADS) is a public agency responsible for agricultural advisory/extension services. One of NAADS' programs was the distribution of banana planting material, either in the form TC, corms or suckers (NAADS, 2018)
	NARO	NARO develops and sometimes distributes new banana cultivars either in the form of TC, corms or suckers (Kilwinger 2017).
	NGO	Some NGOs such as Caritas distribute banana planting material among their members, either in the form of TC, corms or suckers (Kilwinger et al., 2017).
Informal	Large-scale farmer	A large-scale banana farmer within the community.
	Remote farmer	A banana farmer from outside the community. Farmers mainly share banana suckers within the community (Kilwinger et al., 2019b).
	Neighbour	A neighbouring farmer. Farmers often refer to fellow farmers within the community as neighbours even if they are also relatives or friends and not direct neighbours (Kilwinger et al., 2019b).
	Own farm	The own farm. In both districts around 70% of the suckers is sourced from the own farm (Kilwinger et al., 2019b).

After grouping the seed sources, respondents were asked to describe why these two were similar compared to the other one, resulting in a list of constructs and contrasts also called "bipolar word-pairs." From each set of triplets, the sources which were grouped together were noted with the related constructs. When all the triplets were presented and the word-pairs listed, farmers were asked to indicate for each bipolar word-pair, which of the two features they preferred when sourcing banana planting material. Further responses were elicited using a soft-laddering approach. In this free response format, respondents construct ladders with personally meaningful constructs

(Phillips and Reynolds, 2009). Soft laddering is the recommended technique in studies with a relatively small sample size (Costa et al., 2004). The starting points of the laddering was the preferred feature, i.e. the preferred construct of each bipolar word-pairs listed during the elicitation phase. From each preferred construct a series of "*Why is it important to you that ...* " questions were asked. Through asking, a ladder of constructs was created starting from attributes to perceived consequences and personal values. It was emphasized to the respondents that there were no right or wrong answers and that the aim of the interview was to understand their individual preferences.

Analysis

The elicited word-pairs and ladders were coded individually by two researches and thereafter compared and merged. In cases of inconsistencies, the researchers discussed and agreed which code was most suitable using original interview transcripts. Coded responses were categorized into attributes, consequences and values. Thereafter, an implication matrix was constructed to count the number of respondents making direct and indirect links between constructs. The implication matrix was constructed manually using spreadsheet software. From the implication matrix, an overall hierarchical value map (HVM) was constructed showing the links between constructs by transforming individual ladders into chains. A cutoff level of four was chosen for the HVM which means that only links which were mentioned by four or more (13%) respondents were shown. The cutoff level was based on the principle of showing as much links as possible while still remaining with a clearly interpretable HVM (Grunert and Grunert, 1995). Indirect, nonredundant, links were also presented in the HVM if they we mentioned by six or more (19%) respondents. Separate HVMs were created by grouping farmers according to district, production scale (large–small) and sex (male– female). Group sizes for each of these categories differed hence a different cutoff level for each HVM was chosen, aiming to represent chains established by minimally around 20% of the farmers.

RESULTS

Characteristics of the interviewed farmers

In total, 17 men and 14 women were interviewed (Table 2). The total farm size of the interviewed farmers ranged from 0.2 ha to 65 ha with an average of 8.2 ha. In both areas, men reported larger farms and more farm area cultivated with banana than women. Total farm size and area under banana cultivation was larger in the western region (12.2 and 2 ha) than in central (3.9 and 0.6 ha) which resulted in more western farmers being classified as large-scale farmers. In general, about half (48%) of the farmers indicated that they grow improved or introduced cultivars such as FHIA hybrids, Yangambi KM5 and M9. The use of improved cultivars was higher in the western region compared to central (68% and 38% respectively). In both areas, more men reported growing improved cultivars compared to women as well as more large-scale farmers compared to small-scale farmers. More farmers in the central region, men and large-scale farmers, had been beneficiaries of previous banana seed system interventions.

Table 2. Demographic characteristics of the respondents and banana production characteristics of the household per region, sex and farm size.

	Age (years)		Total farm size (ha)		Banana farm size (ha)		Uses improved cultivars (%)	Beneficiary of intervention (%)
All (N=31)	42.6	± 13.8	8.2	± 15.1	1.3	± 1.9	48.7	19.4
Central (n=16)	41.1	± 13.2	3.9	± 7.2	0.6	± 0.6	37.5	25.0
Western (n=15)	42.6	± 13.8	12.2	± 19.3	2.0	± 2.3	60.0	13.3
Men (n=17)	43.8	± 15.3	11.2	± 17.6	1.7	± 2.3	64.7	23.5
Women (n=14)	39.3	± 9.8	4.5	± 10.9	0.8	± 0.9	28.6	14.3
Large-scale (n=11)	40.4	± 12.7	19.7	± 20.0	3.1	± 2.5	72.7	27.3
Small-scale (n=20)	42.6	± 13.6	1.1	± 1.0	0.5	± 0.4	27.3	15.0

± standard deviation

Farmers' perceptions of banana seed sources Farmers were not familiar with all the presented seed sources. In both regions, respondents were least familiar with laboratories (9 out of 31) followed by NGOs and nurseries (11 and 14 out of 31 respectively). The formal source known to most farmers was NAADS (27 out of 31). Farmers in the Western region were less familiar with formal sources. Almost all farmers were familiar with informal sources: only two female farmers from the

Western region mentioned that they did not know any remote farmer they could source planting material from.

Farmers mentioned a total of 24 different bipolar word-pairs during the elicitation phase (Table 3). The number of elicited word-pairs per respondent ranged between 2 and 11 with an average of 7. The most frequently mentioned constructs and contrasts were cultivar related. "Traditional cultivars" and "improved cultivars" were mentioned most often by farmers. "Traditional cultivars" were mainly associated with informal sources and "improved cultivars" with formal sources. The cultivar related word-pair thereafter named most frequently were availability of "other cultivars" and "similar cultivars." With "other cultivars," farmers meant the source provided cultivars which they did not have on their own farms whereas "similar cultivars" meant the source had cultivars they were already growing on their plantation. "Other cultivars" were associated with both formal and informal sources. The formal source most associated with "other cultivars" was NAADS and a remote farmer and a large-scale farmer were the most related informal sources. "Similar cultivars" were mainly associated with informal sources and most often with the own farm. Another cultivar related word-pair was a source with a "high cultivar diversity" available and a "low cultivar diversity." A source with "high cultivar diversity" was mostly related to informal sources. Farmers were also considering whether they could be "sure of the cultivar type," which they related to both formal and informal sources.

Table 3. Constructs and contrasts mentioned during the elicitation phase and the number of farmers relating them to a particular seed source (n=31). LB = laboratory, NS = nursery, NA = NAADS, NR = NARO, NG = NGO, LF = large-scale farmer, RF = remote farmer, NE = neighbour, OF = own farm.

Constructs	Formal sources					Informal sources				Contrasts*	Formal sources					Informal sources			
	LB	NS	NA	NR	NG	LF	RF	NE	OF		LB	NS	NA	NR	NG	LF	RF	NE	OF
Traditional cultivars	-	1	2	1	-	10	8	26	14	Improved cultivars	1	3	15	13	5	5	-	-	-
Similar cultivars	-	-	1	-	-	9	3	9	17	Other cultivars	-	3	8	4	1	9	12	3	-
Close	-	1	-	-	-	8	3	13	13	Far	2	3	7	7	2	6	9	-	-
Unknowledgeable	-	-	-	1	1	2	9	10	7	Knowledgeable	-	1	2	6	2	11	4	2	-
Suckers	-	-	2	-	-	2	5	8	7	TC	3	8	9	7	3	-	-	-	-
Diseases	-	1	3	2	-	-	-	8	8	Disease free	2	6	2	9	1	8	-	-	-
Informal	-	-	-	-	-	4	4	8	3	Formal	5	7	7	9	1	-	-	-	-
Free of charge	-	-	8	-	-	-	4	-	7	Pay cash	4	6	4	3	2	7	-	-	-
Does not innovate	-	-	-	-	-	-	9	10	7	Innovates	1	1	2	6	1	-	-	-	-
Small quantities	-	-	2	-	1	2	4	5	7	Large quantities	3	4	-	-	-	5	2	-	1
Cheap	-	-	-	-	-	-	4	4	-	Expensive	4	6	4	3	2	7	-	-	-
Unsure of cultivar	-	-	2	2	-	-	2	3	-	Sure of cultivar	-	4	1	5	1	6	2	-	6
High cultivar div.	-	-	1	1	-	5	3	3	4	Low cultivar div.	-	1	2	1	-	1	-	2	2
Assessable	-	-	-	-	-	1	1	3	5	Not assessable	-	-	1	1	-	5	2	2	-
Exchange	-	-	-	-	-	3	3	8	3	No exchange	-	1	-	-	-	3	-	-	-
On demand	1	2	-	1	-	1	2	5	3	At their convenience	-	-	3	-	-	-	1	-	-
Low input req.	-	-	-	1	-	3	-	5	1	High input req.	1	2	2	2	-	1	-	-	-
Low quality	-	-	1	2	1	1	-	2	1	High quality	1	1	-	1	-	2	1	-	1
Adapted argo-eco	-	1	-	2	-	1	1	3	3	Not adapted agro-eco	-	-	-	-	-	2	1	-	-
Low resource av.	-	-	-	-	-	-	3	-	2	High resource av.	-	-	-	-	-	6	-	-	-
No disease resistance	1	1	2	1	2	-	-	-	1	Disease resistance	-	-	-	-	-	-	1	1	1
No terms/conditions	-	-	-	-	-	1	2	2	-	Terms/conditions	-	-	4	1	2	-	-	-	-
Familiar	-	-	-	-	-	-	-	1	2	Unfamiliar	1	2	2	1	-	-	-	-	-
Trusted	-	1	-	-	-	-	-	-	-	Not trusted	-	1	-	1	-	-	-	-	-

* Sources are presented in multiple triplets linking one source to a construct and two sources to the contrast. Which attribute is the construct and which the contrast differs per respondent. For ease of interpretation of each word-pair one is presented in this table as the construct and one as the contrast.

Apart from the cultivars available at the source, an important feature for farmers was whether "suckers" or "tissue culture plantlets" were available. "Tissue culture plantlets" were only related to formal sources and "suckers" to informal sources and NAADS. Other word-pairs related to the planting material available at the source were if the material was "free of diseases" or "diseased," whether there was a "high quantity" available or a "low quantity," if managing the material required a "high resource input" or a "low resource input," if the material was "adapted to agro-ecological" conditions or not, and if the material was "disease resistant" or not.

Next to word-pairs related to the planting material, farmers made constructs and contrasts based on the acquisition procedure. The most frequently mentioned word-pair was a source "located close" and one "located far away." Informal sources were mostly perceived as "close by" and formal sources, a remote farmer, and a large-scale farmer as sources "located far away." Another frequently mentioned word-pair was whether the source was "knowledgeable" or "unknowledgeable." A "knowledgeable source" was described as a source where farmers could obtain additional advice on proper management of the planting material and their banana plantation in general. Large-scale farmers and formal sources were mostly perceived as a "knowledgeable" source whereas neighbors were perceived as "unknowledgeable." Farmers also mentioned a "cash payment" requirement or if the planting material could be obtained "free of charge" via "exchange," if the material was "expensive" or "cheap," if the source was "innovative," if the source was "familiar" to them and if certain "terms and conditions" needed to be met while acquiring the material. With "terms and conditions" farmers meant the material could not be obtained "on demand" when they need it. Instead, the acquisition procedure involved "terms and conditions" such as subscription requirements, farm inspections, a limited quantity and no free choice in cultivar type. Formal sources were mostly related to "cash requirements," "expensive," "innovative," "unfamiliar" and involving "terms and conditions." Attributes that can be related to seed system intervention such as meeting terms and conditions, the type of planting material available and a cash requirement were more frequently mentioned by farmers from the study site in Central Uganda compared to Western Uganda.

Relating attributes, consequences and values while selecting a seed source

The number of ladders constructed per farmer ranged between 3 and 36 with an average of 16. In the HVM, 42 constructs appear, which is 47% of the total named constructs. Between the constructs, 51 direct links are shown representing 12% of the total number of direct links made between constructs (Figure 1). The construct mentioned by most farmers was "higher income." Farmers said it would be used to "sustain" and "develop" the household and have a "better future." The majority of farmers said a high income resulted from "increased yield," "marketable products," and products which could be

used for "multiple purposes." An increased yield was mostly related to "improved management" after farmers had "gained knowledge." An increased yield was also related, by fewer farmers, to "disease free" planting material and "timely planting." Most farmers attributed marketability to a "big bunch." With "multiple purposes" the farmers meant the produce could be used for income, food and other purposes leading to "food security." Products with multiple purposes resulted from having a farm with "diverse cultivars." Most farmers linked this to a source with a "high cultivar diversity" or "other cultivars." Other benefits of a farm with diverse cultivars were "risk avoidance," because each cultivar has its own "strengths and weaknesses."

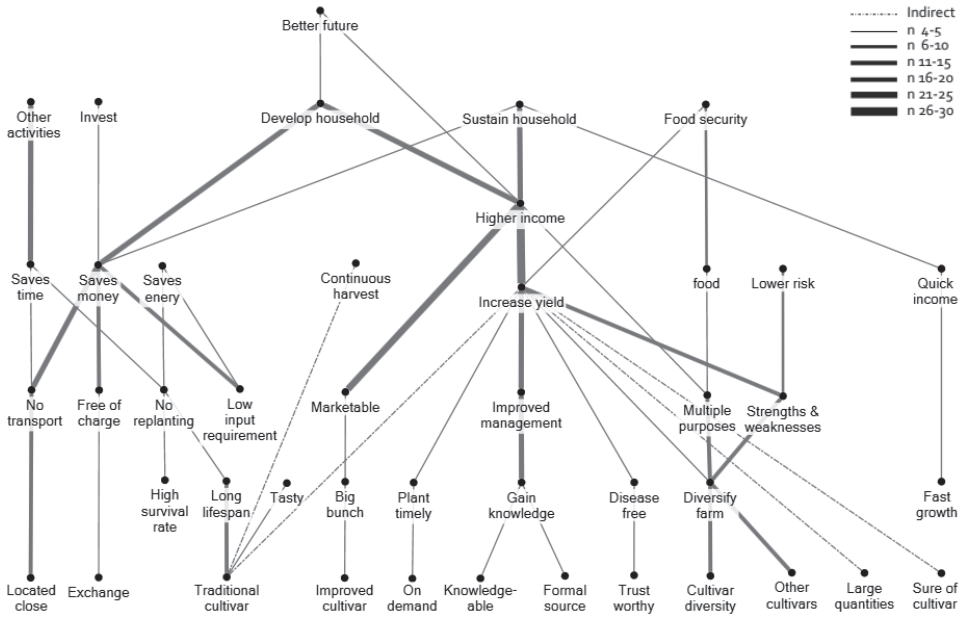


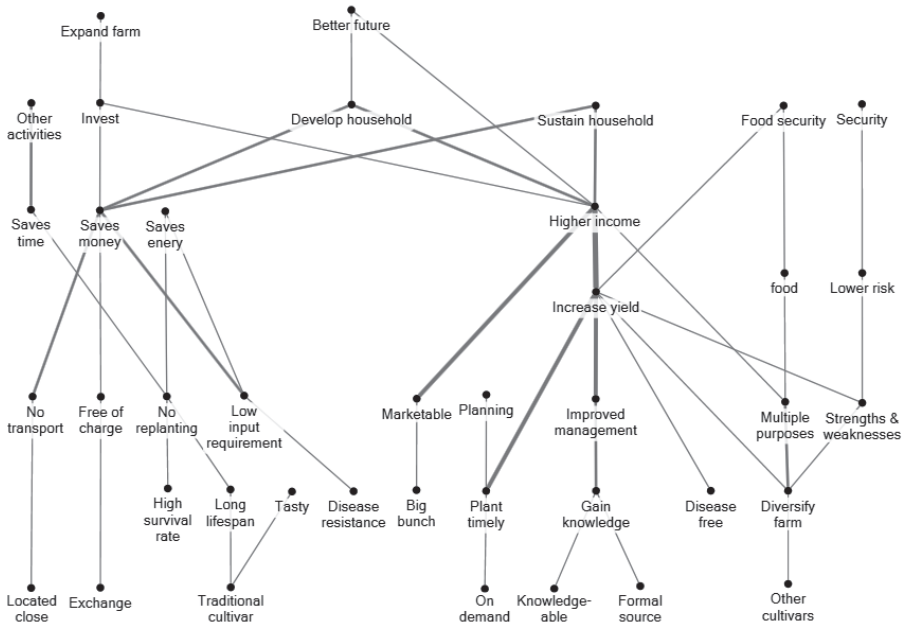
FIGURE 1. Hierarchical value map based on the number of respondents making a link between constructs. The thickness of the lines correlates with the number of respondents making a link. Nonredundant, indirect, links between constructs are indicated with a dashed line. n = 31; cutoff level n = 4.

Farmers mentioned other financial gains besides increasing the income. They also took into consideration how the money would come into the household and made a distinction between "higher income" meaning more income is generated, "saving money" by not having to spend money, "quick money" meaning a relatively large sum is obtained in a short time, and a "continuous flow of money." Saving money was

mostly linked to similar values as a high income but resulted from different consequences such as "free" planting material, "no transport" requirement and cultivars with "low input requirements." These were in turn linked to attributes which were mainly related to informal sources such as nonmonetary "exchange" of planting material and a source in a "nearby location." Besides saving money, it was important for farmers to "save time" and "save energy" which were also mainly linked to attributes related to informal seed sources. Farmers valued saving time because this allowed them to do "other activities" besides farming.

Differences in hierarchical value maps of Central and Western Uganda.

Many chains in the HVMs of Central and Western Uganda were overlapping but the HVM of Central presented more links (Figure 2). The most dominant pathway in the overall HVM—"gaining knowledge" to "high income"—was represented in the HVMs of both areas. Gaining knowledge was related to "formal" sources by farmers from Central and to a "knowledgeable farmer" by Western farmers. In the HVM of Central, the bipolar constructs "exchange" and "no exchange" of planting material appeared whereas in the HVM of Western none of the two appeared. Farmers from Central Uganda preferred sources that exchange planting material because it is "free"; and sources that do not exchange planting material because the material is more likely to be "disease-free." They also associated disease-free planting material to formal sources. Western farmers related disease-free planting material to "trustworthy sources." "Disease resistance" only appeared on the HVM of Central but was not sufficiently linked to a single attribute reaching above the cutoff level. Another chain that was represented only in the HVM of Central Uganda was planting material that can be obtained "on demand" which enables farmers to "plant timely" leading to higher yields. In the HVMs of both Central and Western Uganda, a "diversified farm" appeared. In Central, farmers related a diverse farm to "multiple purposes" and "avoiding risks." In Western a diversified farm was linked to risk avoidance only. The relation between "traditional cultivars" and a "tasty" product only appeared in the HVM in Central, whereas "fast growing" planting material and "quick income" only appeared in the HVM of Western.



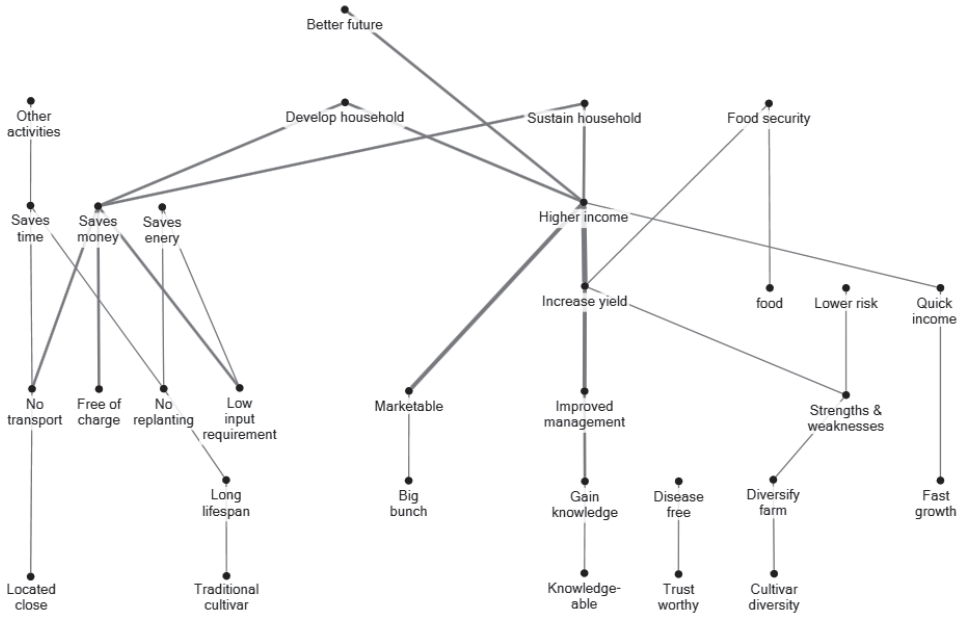


FIGURE 2. Hierarchical value map based on the number of respondents making a link between constructs of the study site in the (a) central region (n = 15; cutoff level n = 3) and (b) western region (n = 15; cutoff level n = 3).

Differences in hierarchical value maps large-scale and small-scale farmers.

Similar to the HVM of Central and Western Uganda, there were a lot of overlaps between the HVMs of the large and small-scale farmers (Appendix 2). The main difference was that the HVM of the large-scale farmers contained almost twice as many links as that of smallscale farmers. The most dominant chain in the overall HVM, from "gaining knowledge" to "higher income," was represented in both the HVMs. Large-scale farmers linked gaining knowledge to "formal" sources and sources who put a lot of effort in "innovation" whereas small-scale farmers related it to a "knowledgeable" farmer. Gaining knowledge was linked to a source that is innovative only in the HVM of large-scale famers. Two other chains that appeared only on the HVM of large-scale farmers, which were also not present in the overall HVM, were improved cultivars linked to "disease resistance" and "tissue culture (TC)" planting material linked to "disease-free" planting material. Large-scale farmers associated disease-free planting material with "formal" and "trusted" sources. The chain from "on demand" to "plant timely" was only represented in the HVM of the large-scale farmers. Chains that only appeared on the HVM of small-scale farmers and were absent on the HVM of large-scale farmers were "traditional cultivars" for their "long lifespan," and free "exchange" of planting material because there was no monetary cost. Attributes appearing in the HVM of large-scale farmers such as "innovative," "TC plantlets," "improved cultivars," and "formal" were linked mainly to formal sources (Table 3). Large-scale farmers mentioned more values compared to small-scale farmers. All the values that appeared in the HVM of small-scale farmers also appeared in the one for large-scale farmers. In addition, large-scale farmers constructed chains from making "investments" to "expanding the farm" and from "higher income" to "self-direction" and "status."

Differences in hierarchical value maps between men and women.

In the HVM of both men and women, the most dominant chain from "gain knowledge" to "high income" was present but there were differences in the related attributes: men linked gaining knowledge to "formal" sources and women to a "knowledgeable" farmer (Annex 2). The largest difference between the HVMs was that men created chains from both "improved" and "traditional" cultivars whereas in the HVM of

women only "traditional cultivars" appeared. Men preferred improved cultivars because of their "big bunches," "fast growth" and for providing "quick income." Both men and women associated traditional cultivars with a "long lifespan" which is valued because it requires "less replanting." Men also valued traditional cultivars because they are "adapted to agro-ecological" conditions in their fields and therefore yield big bunches. The link between "time saving" and "other activities" appeared in both HVMs but was mentioned more often by women compared to men. In addition, the chain "on demand" and "plant timely" was only present in the HVM of the women. Both men and women pursued similar values such as food security and, sustaining and developing the household.

DISCUSSION

Source characteristics

The results show that when selecting a source for banana planting material, farmers take more attributes into consideration than only the type of planting material available. Farmers also considered diversity of available cultivars, the chances of finding new ("other") cultivars, quantities of planting materials available and the timing of the availability. Although source characteristics related to the available planting material were most frequently mentioned, farmers also considered knowledge availability, transportation requirements, trustworthiness and transaction conditions when choosing seed sources. The majority of the identified attributes have been described and discussed in literature (e.g. Sperling, 2002; Kabunga et al., 2012a; Murongo et al., 2019; Muyanga, 2009). Yet, some of the attributes, especially the ones in the social domain and related to diversity, are seldom described.

How farmers related attributes to sources differed among, but also within, formal and informal sources. For example, NAADS—like the informal sources—was perceived as a free source, whereas other formal seed sources were not. Large-scale farmers had many overlapping attributes with formal sources such as "knowledgeable," "sure of cultivar" and "disease free," but were also perceived by some farmers as "inaccessible" and "expensive." This supports the claim that within informal seed networks, seed does not just move fluidly between farmers without barriers and at minimal cost (Coomes

et al., 2015). Seed sources, either formal or informal, not only differ in the seed they have available, but also their acquisition procedures, and thus attractiveness. These factors beyond the performance of the material can facilitate or hinder purchase and adoption. Seed in this way is not a fixed entity; it is reconstructed and reconfigured as it is handled by different actors (Glover et al., 2019). It also supports notions that seed systems are similar to innovation systems and as such harbor complex interactions between social and technical components (Glover et al., 2019; McGuire 2008).

Pursued benefits

When sourcing planting material, farmers pursued more benefits and goals than merely an increase in yield and income. Farmers looked for planting material that could be used for multiple purposes, required less time and labor to manage and that would reduce risks. These other benefits and goals were mainly related to traditional cultivars and a high cultivar diversity, which in turn were mostly associated with informal seed sources. Formal sources in collaboration with informal sector could therefore ensure that they have necessary diversity demanded by farmers given the values that farmers associate with a diverse portfolio of cultivars.

Farmers did not only point out that financial gain is important, they also indicated the importance of the amount, timing and frequency of these gains. Attributes related to informal sources such as exchanging planting material and no transport requirement were mainly valued because they lead to a reduction in expenditure—i.e. they saved money, whereas attributes related to formal sources, such as big bunches and clean planting material, were mainly valued because they generated income. Planting material from different sources can thus result in different types of financial gains. For example, availability of large quantities of planting material of a single cultivar can lead to a large and uniform harvest over a short time span, resulting in a large sum of money at once (quick income). Having a high cultivar diversity on the other hand can lead to staggered harvest times and thus, a continuous harvest and smaller but continuous amounts of cash income.

In the field of development economics, this is referred to as an "income smoothing mechanism" (Morduch, 1995). Income smoothing mechanisms used by rural

households in developing countries include e.g. labor diversification within the household, crop diversification and migration (Barrett et al., 2001; Pellegrini and Tasciotti, 2014). The results of this study suggest that banana cultivar diversification is another mechanism used by farmers for income smoothening, risk avoidance and food security. Continuous harvest and income were mentioned by one-third of the farmers but were not sufficiently linked to other constructs to appear in the hierarchical value map. There was no specific group of farmers that mentioned these constructs which explains why they also did not appear on the grouped HVMs. Preferences in income distribution might differ among farmer or household typologies and change over time. In some periods, farmers might need more income, for example during the time when school fees have to be paid. School fees, classified under sustaining the household in this research, was frequently mentioned by farmers. During the time when school fees have to be paid, farmers might also prefer to source planting material from their own farm and save money over buying planting material.

Different pathways to shared values

The HVMs derived from different groups of farmers showed many similarities, especially at the values level. This suggests that farmers pursue similar goals but identify different pathways to reach these goals. For example, the pathway from gaining knowledge to a higher income was most dominant and represented in all HVMs. Where farmers seek this knowledge differed per group. Farmers from Central Uganda, large-scale farmers and men perceived formal sources as an important place to obtain knowledge whereas farmers from Western Uganda, small-scale farmers and women more often perceived a knowledgeable fellow farmer as a source to obtain knowledge. Not all formal sources were perceived as knowledgeable. Providing knowledge next to planting material itself seems to be important to make a source attractive to farmers. Access to knowledge was found to be an important factor for adoption of TC plantlets (Kabunga et al., 2012b). Large-scale farmers, frequently referred to as knowledgeable in this study, may provide an important role for farmers in the community that cannot directly access information from formal actors.

Observed differences between the study sites in Central and Western can be related to seed system interventions, cultivation history and production objectives. Attributes related to formal seed sources, which farmers usually get familiar during interventions, were mentioned more often by farmers from Central Uganda. Farmers from Central Uganda valued high cultivar diversity because of the multiple purposes of banana, which seems less important to farmers from Western. Multiple purposes, meant banana products could be sold and used in various ways, indicating emphasis on both marketing and home use. The appreciation of large-scale farmers for attributes related to formal sources of planting material points to their commercial interests, but at the same time the HVMs show that they also appreciate benefits from attributes related to informal sources. Large-scale farmers have not dropped the traditional use of banana as a multipurpose livelihood product, meaning they are in a way "dualistic": they maintain the profile of traditional smallholder farmers and are adding considerations that are typical for commercial larger farmers with interests in economic gains. The overlap between large-scale farmers and men can explained by the fact that large-scale farmers were more often male and suggests men are more market-oriented than women, which is also found by Rietveld et al (2020). The market orientation is related to valuing improved cultivars for their big, marketable bunches and for their fast growth leading to quick income. Small-scale farmers and women on the other hand perceived more benefits from traditional cultivars. Women valued time availability for other activities more than men, possibly because women have multiple chores in the household and could have their own crop priorities (Kasente et al., 2002).

CONCLUSION

The means-end chain analysis has provided insights in how different types of farmers perceive various sources of banana planting material and why they value them. The use of triatic sort and soft laddering approach allowed us to capture farmers" considerations while avoiding preselection and predefinition of any attributes. This resulted in answers which might not easily emerge in survey-based data collection. The importance of obtaining knowledge while sourcing planting material was striking, in

combination with the finding that larger and male farmers considered the formal sources to obtain knowledge, whereas smaller farmers and women saw more opportunity to obtain knowledge from informal sources. Another finding was that not only the amount of income generated is important to farmers, but also the timing and frequency of incomes.

The availability of diverse cultivar types is a very important attribute of an attractive source of banana planting material to all types of farmers but in addition farmers considered many aspects of seed sources which are unrelated to the type of cultivar or planting material. These included the location of the source, the transaction type, the availability of knowledge, trustworthiness, the time planting material is available, and required labor and time investments to manage the planting material. Thus farmers do not merely look for clean and high yielding planting material that can increase income but take more characteristics related to of the source and the planting material in consideration. The goals farmers pursued while sourcing banana planting material were mainly overlapping. The attributes and consequences farmers presumed would lead them to these goals differed among farmers. For example, some farmers" strategy to sustain the household was use of free planting material of traditional varieties that would save them money whereas other famers invested in improved varieties that generate more income.

In this paper we described the results of a case study on farmers" perceptions of banana seed sources. Due to the relatively small sample size, sampling strategy, and the limited information on this topic yet available, we cannot make any claims about the external validity and generalizability of the outcomes. What we can conclude is that among the interviewed farmers not only seed, but also seed sources, matter, and that farmers have diverging perceptions on the attractiveness of these source when seeking new planting materials. This is an important consideration for seed system interventions. In the case of introduction of tissue culture banana plantlets, it means that failure of adoption is not necessarily found in the performance of the technology itself. Tissue culture plantlets were mainly available at formal seed sources or distributed as part of government programs. Formal sources are not equally attractive/accessible for all

farmers and involve a rather different acquisition procedure. Careful consideration of the sources at which improved planting material is made available could improve seed system interventions.

In general, we identified that perceived benefits and disadvantages of seed sources differ among farmers. Understanding these differences in preferences among farmers is relevant for seed system interventions in order to strategize on seed delivery pathways. Aggregation of this type of information could result in the definition of "delivery profiles": these would not only comprise cultivar traits and client profiles that breeders seek to suit different farmer typologies (Ashby and Polar, 2019)—but would also include contextual agro-ecological and socioeconomic variables which facilitate accessibility of the planting material. Such "delivery profiles" would be of strategic importance to projects that aim to reach differentiated groups of farmers with new cultivars, clean planting material and disease management

CHAPTER
Five

Understanding smallholder farmers' economic valuation for vegetatively propagated seed via experimental Vickery auctions: A theoretical reflection with experiences from the field.

Authors

Fleur B.M. Kilwinger [1,2] , Conny J.M. Almekinders [1,2] , and Ynte K. van Dam[3]

[1] CGIAR Research Program on Roots, Tubers and Bananas (RTB)

[2] Knowledge, Technology and Innovation, Wageningen University and Research (WUR)

[3] Marketing and Consumer Behaviour Group, Wageningen University and Research (WUR)

ABSTRACT

Experimental auctions are increasingly applied to understand smallholder farmers' valuation of (vegetative) seed in developing countries. We explore the methodological appropriateness and usefulness of Vickrey auction in that context, using literature and experiences from a Vickery auction among Rwandan sweetpotato farmers. In this context, we find that four core assumptions of auction theory might be violated and discuss the implications for the validity of the different measurements that can be derived from Vickrey auctions. First, we find farmers might lack reference prices that result from previous purchase experience of comparable goods. We recommend to explore what farmers use as reference prices in these situations and whether and anchoring effect occurred, especially if the magnitudes of bids are used for pricing policies. Second, we find that the characteristics of vegetative seed as a good differ from those that Vickrey auctions are generally used for. Vegetative seed can be multiplied while maintaining genetic traits, and is commonly shared among farmers as a cultural practice. This lowers the predictive validity of auctions for estimating future and long-term demand. Third, we found indications that some farmers might construct preferences and values differently in real-life than in the experimental setting which lowers external validity of the auction results. And finally, when auctions are used to estimate how farmers value information, their knowledge levels prior to the experiment should be equal or controlled for. We conclude that the experimental (Vickrey) auction is an interesting research method to contribute to our understanding of farmers' decision-making regarding seed, but adaptations of the research design might be required to make it more compatible with this specific context depending experiments objective(s).

INTRODUCTION

Experimental auctions as a tool in seed system research

Development of a commercial seed system is increasingly seen as an economically sustainable solution to improve smallholder farmers' access to quality seed and improved varieties (e.g. Campos, 2021; Neate and Guei, 2010; CtEH, 2021), and is considered vital for returns of investment in crop improvement research (Maredia et al., 2019). Other benefits associated with effective commercial seed systems that contribute to food security and poverty alleviation are a faster varietal turnover and attraction of private sector investments (e.g. Barker et al., 2021; Donovan et al., 2021; CtEH, 2021). To enable development of commercial seed businesses, there is a need for a long-term demand forecast through market research (Barker et al., 2021; Maredia et al., 2019).

Vegetatively propagated staple crops are important food and cash crops in many parts of the developing world, and their seed systems are predominantly informal (McEwan et al., 2021). Estimating the market demand for the planting material of vegetatively propagated crops, hereafter called vegetative seed, is challenging because farmers can have various reasons and different ways to replace (or not replace) their seed that depend on multiple agro-ecological and socio-economic conditions (Almekinders et al., 2019a).

Recently, experimental auctions have gained attention as potential research method to better understand the demand of vegetative seed among smallholder farmers (Andrade-Piedra et al., 2020; Delaquis et al., 2019; Almekinders et al., 2019b; Pircher and Almekinders, 2021). Experimental auction studies are a relatively new research tool in rural Africa, but are growing in number to understand demand for agricultural products (e.g. Rousu, 2015; Lusk and Hudson, 2004; De Groote et al., 2011). Such economic valuations, or willingness-to-pay (WTP) studies, can support understanding of the monetary value people place on non-market goods, or goods circulating in imperfect markets (Canavari et al., 2019). Demand curves derived from willingness-to-pay estimates can further be used to understand consumer preferences and behaviour, to forecast new product success or market responses to price levels, and to support pricing

policies by locating the position on the demand curve that maximizes profit (Lusk et al., 2007; Luks and Hudson, 2004; Breidert et al., 2006; Canavari et al., 2019).

As compared to contingent valuation methods, the experimental auctions - also referred to as experimental valuation methods - are considered to be non-hypothetical and therefore give better estimations of willingness-to-pay (Grunert et al., 2009). Experimental auctions have been predominantly developed and applied for non-market and hypothetical goods in Western industrialised countries. This raises concerns about the practical and theoretical ramifications when copying these methods in other contexts, such as in rural African communities (Morawetz et al., 2011). Moreover, many studies do not present insights in the way participants of auctions understood what they were engaged in, why they acted the way they did, whether they would have acted differently upon reflection, or if they knew which hypothesis they were supposed to confirm (Streeck, 2010). In addition to those concerns, (vegetative) seed has characteristics of a rather peculiar good because it can be multiplied while maintaining genetic character and the dominant exchange mechanisms among farmers which are based on social norms and values rather than market principles (McGuire, 2008; Coomes et al, 2015). Adding these considerations together, we argue that the application of experimental auctions in the field of smallholder farmers' demand for (vegetative) seed requires reflection on its methodological appropriateness.

The main objective of this paper is to explore the methodological assumptions underlying experimental auctions and how these may affect the use of their outcomes to understand the demand for seed among smallholder farmers with a focus on vegetative seed in rural Africa. We use experiences of a Vickrey or second-price auction that aimed to find the premium price Rwandan farmers are willing-to-pay for clean vines of a biofortified sweetpotato variety. Vickrey auctions (Box 1) are deemed 'incentive compatible', given a set of assumptions. It should be determined if these assumptions hold for the good and context in which the auctions are conducted (Lusk and Shogren, 2007). We elaborate on the assumptions underpinning the Vickery auctions for vegetative seed as the auctioned good in the context of smallholder farming in Africa. We discuss the implications for the validity and usefulness of

experimental auctions to measure preferences, estimate demand and predict future behaviour in this specific research field.

Box 1

Economic valuation, Vickrey auctions and incentive compatibility

Vickrey auctions were developed in 1961 to determine a 'counter-speculative price' or 'competitive equilibrium price' in imperfect markets to optimize resource allocation (Vickrey, 1961). During a Vickrey auction participants place their bids in a sealed form, for example an envelope. The participant with the highest bid wins the auction but only has to pay the price of the second highest bid (i.e. second-price auction). Vickrey auctions are said to be 'incentive compatible' because a respondents' own bid does not define the actual price paid, but only defines whether the respondent is allowed to purchase (Grunert et al., 2009). This mechanism provides participants with an incentive to reveal their true valuation: when overbidding the participants risks paying more money for the good than their true value, and when underbidding participants risk to miss out on a good deal (Rousu, 2015; Lusk and Shogren, 2007). This incentive compatibility and the possibility to attach real economic consequences are attractive properties of Vickrey auctions. It can therefore be assumed that when participants act rationally, they will display an optimum strategy, which is revealing their true, maximum, willingness-to-pay (Vickrey, 1961; Canvari et al., 2019; Grunert et al., 2009).

Assumptions that might be violated

Based on a literature review, we formulated 4 propositions on assumptions that are possibly violated when experimental (Vickrey) auctions are applied in the context of vegetative seed in rural Africa. We discuss the assumptions on four aspects: the economic valuation of vegetative seed, vegetative seed as an economic good, rational bidding of participants, and the situation of asymmetric information.

Assumption 1:
Farmers have an economic monetary valuation for vegetative seed

Experimental auctions applied to seeds specifically aim to 1) reveal farmers' preferences for different seeds (Waldman et al., 2014), 2) measure farmers' willingness-to-pay (Okello et al., 2018; Mastebroek et al., 2020; Morgan et al., 2020; Gharib et al., 2021), 3) measure farmers' willingness-to-pay premiums (Maredia et al., 2019; Gharib et al., 2021), 4) define relative demand among seeds (Maredia et al., 2019; Gharib et al., 2021), and 5) to predict future behaviour by estimating effects of demographics or interventions on adoption of seeds (Mastenbroek et al., 2020; Morgan et al., 2020). Although those objectives are slightly different, this is always done by measuring the value farmers give to seeds expressed in monetary terms.

One objective to conduct experimental auctions is to find the economic value for a good or service that has no known price. Nevertheless, there are concerns related to this monetary measurement for a good, i.e. (vegetative) seeds, that in real-life farmers predominantly access from informal seed sources. Therefore, firstly, reference prices might be absent and it remains largely unknown what effect absence of reference prices has on auction results. Second, because reference prices are absent the chances that an anchoring effect occurs increases.

Consumers form internal 'reference prices' based on previous experiences with prices of the same or similar goods. This reference price provides an anchor that is used to judge the current price of a good (Putler, 1992). Either explicit or implicit, such internal reference prices affect perceived utility and influence purchasing behaviour (Putler,

1992). Furthermore, this previously processed price information forms an important determinant of a 'reservation price': the highest price a consumer is willing-to-pay for a good (Grunert et al., 2009; Roy et al., 2016; Briesch et al., 1997).

Contrary to consumers, smallholder farmers in rural Africa predominantly access vegetative seed via informal seed systems (e.g. Pircher et al., 2019; Kilwinger et al., 2019b; Stuart et al., 2021). Informal seed systems are characterized by farmers' own reproduction of seed, using their own selection practices and production conditions (Almekinders et al., 1994). Often seed is saved for the next planting season and shared with other farmers. Although situations in which vegetative seed is sold via a cash transaction are increasingly reported, exchange within farmers' networks based on cultural norms and social relations remains the dominant way of acquisition (McGuire, 2008; Tadesse et al., 2017; Almekinders et al., 2020). Acquiring and hence valuating vegetative seed using cash might therefore be unfamiliar for many farmers.

Because some farmers might have never purchased seed but have always acquired it via other exchange mechanisms, such as gifts and barter, it remains unknown what they will use as their reference price. If reference prices are absent, the chance that an anchoring effect occurs increases: an initially presented, irrelevant, value is used as a reference point when making an estimate, i.e. defining a reservation price (Tversky and Kahneman 1974; Furnham and Boo, 2011). This makes inclusion of a practicing round with an unrelated item tricky as participants might anchor around the value of that item. Practicing rounds are often required to make participants understand the auction mechanism and are done with items of which the value is well known to participants (Lusk and Shogren, 2007).

Assumption 2:
Experimental auctions are suitable for vegetative seed as economic good

When experimental auctions are applied to measure smallholder farmers' valuation of vegetative seed via a monetary/economic value, it is presumed that (vegetative) seed is an economic good. There are different types of economic goods, and when

characterizing (vegetative) seed as such, we find divergences from the average traded commodity that experimental auctions are normally used for. Vegetative seeds can be cloned and reproduced, and after multiplication can benefit multiple users. We expect those specific characteristics will affect farmers bidding behaviour and will have consequences for the demand curves derived from experimental auction data. In the following we reflect on the character of (vegetative) seed as a good.

A good can be characterized by its own properties in combination with the properties of its users. Plants/crops have rather peculiar properties when characterizing them as economic goods. Seeds (both true and vegetative seeds) have dual properties: they form the basic *input* (the plant parts used for production) and *output* (the plant parts used for consumption) for plant-based agricultural systems. In crops like potato, yam or beans even the same plant parts are used for both consumption and production. In a crop like cassava and banana these are different parts of the plant.

Experimental auctions are relatively common tools in agricultural economic research to estimate *consumers'* willingness-to-pay for *agricultural outputs* (e.g. Corrigan et al., 2009; De Groote et al., 2011; Nalley et al., 2006). Experimental auctions for *seeds as input* and how *farmers* value them are more scarce. There are important differences to take into consideration when experimental auctions are used to value seed as agricultural output or as agricultural input; these relate to the durability and hence frequency of purchase. First, 'seeds' auctioned for consumption can be consumed only once by a limited number of users. In contrast, seeds auctioned as an input for production can reproduce themselves: while the same seed cannot be used more than once, it has the potential to provide new seeds for the following production cycle.

Secondly, the type of seed is important. Economic valuation studies often focus on farmers' willingness-to-pay for genetic traits. Because vegetative propagated crops reproduce clonally, material with similar genetic traits can be reproduced for countless cropping cycles (in principle, if material would not degenerate and could be multiplied limitless). Vegetative seed shares comparable properties with for example open pollinated crops, but differs in this aspect from true seed hybrid crops. Because true seed hybrid crops are reproduced generatively, the heterosis or 'hybrid vigor' effect

and genetic uniformity disappear after reproduction. Therefore, to obtain similar genetic traits, farmers cannot save seed and instead have to purchase new seed each cropping season, representing a phenomenon that is also referred to as 'economic sterility' (Kloppenburg, 1988).

Another important determinant of seed performance, next to its genetic traits, is physiologic and sanitary quality (hereafter referred to as 'seed quality' and 'quality seed'). When reproducing seed vegetatively, there is a high risk that pests and diseases remain with the planting material. This can result in the built-up of pathogens over successive cycles of reproduction, a phenomenon referred to as seed degeneration (Thomas-Sharma., 2016). Seed degeneration and its expression in yield is a complex process that depends on many interacting agro-ecological and socio-economic factors such as climate and management (Navarrete et al., 2022). Therefore, it is often unclear for how many subsequent seasons farm-saved seed might perform sufficiently and when farmers' investments in quality seed become beneficial.

Apart from the reproductive characteristics of seeds, and specific characteristics of different types of seed, the characteristics of its users are also relevant. Users can interact in different ways with similar goods. For example, in Uganda banana is grown by many smallholder farmers for subsistence, to fulfil multiple end-uses, and has an important cultural meaning (Kilwinger et al., 2019b; Mulumba et al., 2004). To meet their needs, farmers in this region mainly save their own seed and share a high diversity of endemic banana varieties. On the other hand, there are farmers who produce for a large commercial and/or export market. Such farmers might be partially or entirely embedded in formal seed markets.

In sum, vegetative seed used by smallholder farmers diverges in many aspects from the type of good for which most experimental auctions are originally designed and normally used. Vickrey (1961) refers to the nature of auctioned products as: *"a single unique indivisible object, to be sold, to one of a number of potential purchasers"*. Vegetative seed is not a 'single, unique and indivisible object': it can be cloned and reproduced. The number and uniqueness change over time as the material is multiplied and distributed by farmers, i.e. it gets 'absorbed' into networks of farmers exchange

(Barker et al., 2021). Therefore it cannot just be used by 'one purchaser'. Vegetative seed might initially be sold to a single purchaser, but many fellow farmers can benefit from this purchase in following planting seasons.

Assumption 3:

Farmers' dominant bidding strategy is to reveal true willingness-to-pay.

It is assumed that when participants act rationally in experimental auctions, the dominant strategy is to reveal their true, maximum, willingness-to-pay. Nevertheless, we consider that farmers might have (unknown) values or goals in the experiment other than those assumed by the researchers, that social norms and informal rules can influence farmers' bidding strategies, and that farmers might construct their preferences differently in the experimental setting than in real-life. If this is the case, then basic assumptions about rationality, strategies and beliefs underlying the action theory are affected.

According to neoclassical economic theory, on which the Vickrey auction is based, people act rational: their decisions are based on the objective to maximize expected utility. Observed differences in bids thus reflect perceived differences in utility. The axioms of utility further assume that people make decisions based on a preference order which is stable, complete and transitive (von Neumann and Morgenstern, 1944). This implies that each individual has goals, which can be captured in an objective function or preference ordering. It is further assumed that an individual chooses the best strategy that maximizes the outcome of this objective function, and that all individuals in a particular situation maximize the same objective function (Mueller, 2004).

However, according to Shogren et al. (1994), common knowledge about each bidders rationality, beliefs and strategies is one of the least plausible presumptions in experimental auctions. Neoclassical economic theory has been subject to a stream of criticism for example from behavioural, evolutionary economics and game theory (Mueller, 2004; Etzioni, 2010; Berndt, 2015; Mendola, 2007). This has resulted in alternative approaches to understand decision-making. These approaches are partially

overlapping and it seems blurry to which school of economic thought they exactly belong (Berndt, 2015); discussing this is beyond the scope of this paper. Instead, we reflect on three common approaches which we deem relevant in for our case study and that relate to: 1) non-standard believes; 2) non-standard decision making; and 3) non-standard preferences (DellaVigna, 2009).

Non-standard beliefs. In this approach, it is generally assumed that individuals act rational, but may have different objectives (Mueller, 2004; Poire, 2010). Findings of psychology and other social sciences are used to inform the assumption of what it is that an individual maximizes, meaning, what variables go into an individual's utility function. Regarding experimental auctions, this could imply that a person may not strictly bid a true value if they have (unknown) goals that extend beyond the immediate experimental context (Lusk and Shogren, 2007), resulting - in the view of the researchers - in sub-optimal bidding strategies. For example, participants might derive utility from the believe that their bid could influence the price at which the auctioned good will later be available in the marketplace, from making themselves look good in front of researchers (social desirability bias), or when they try to win the auction just for winning's sake (Lusk and Shogren, 2007).

Non-standard decision making. In this approach the assumption that individuals maximize utility is criticized. It is argued that people do not, and cannot, maximize (Etzioni, 2010). A famous example is provided by Simon, (1972) who demonstrated that while making a choice individuals stop searching for better alternatives once they are satisfied. He presents this as routines, habits, or rules of thumb that people in the real world follow to simplify decision making. In such situations the concept of 'bounded rationality' is used. These kinds of 'shortcuts' in decision making could also result from common practices and other social norms and rules. Instead of making a decision based on a full cost-benefit analysis, people might select the option which is considered appropriate, normal or expected. Such considerations result in different predictions and interpretations of economic behaviour as compared to the neoclassical paradigm.

Non-standard preferences. In this approach, the axioms of utility are criticized. Compared to economic theories, psychological theories take a different perspective on decision making. In such theories, choices are generally not based on a stable, complete and transitive preference order, but constructed as needed in a particular context. Such a theory acknowledges the existence of relatively stable attitudes and preferences in familiar contexts, but emphasizes the liability of preferences and their susceptibility to framing effects and to variations of context and elicitation procedures (Kahneman et al., 1993). The conditions in which smallholder farmers make decisions in real-life might be rather different from the experimental setting and its underlying assumptions. Their valuations during the experiment might thus be constructed for the specific situation and therefore do not reflect actual preferences outside experimental conditions.

Assumption 4:

Experimental auctions can be used to estimate farmers' valuation of information.

Experimental valuation methods can be used to understand changes in valuation under different conditions. A lack of information on benefits of agricultural innovations among smallholder farmers is considered an important bottleneck for their adoption (Mastenbroek et al., 2020). Experimental auctions have been used to understand if farmers update their valuation when information on benefits or drawbacks of different types of seed is provided (e.g. Mastenbroek et al., 2020; Okello et al., 2018; Waldman et al., 2014). One of the four assumptions underlying the benchmark model for experimental auctions developed by McAfee and McMillan (1987) is that bidders possess symmetric information. We argue that relaxing this assumption might be problematic if the objective of the auction is to measure differences in valuation based on 'new' information.

Vickrey auctions assume symmetric information among buyers, but are designed for, and can be used in, situations of asymmetric information (Vickrey, 1961; Sandmo, 1999; McAfee and McMillan, 1987). Asymmetries of information are common in economic exchanges. Often, one party to an exchange knows something relevant to that transaction that the other party does not know (McAfee and McMillan, 1987).

Buyers and sellers usually have different information on the good or service to be traded, especially if the value of the item is uncertain (Akerlof, 1970). A provider or seller of a good in this situation might want to know the willingness-to-pay of consumers, but the only people who possess this information are the consumers themselves (Sandmo, 1999).

In such situations of asymmetric information between buyers and sellers, Vickrey auctions can be used to reveal preferences and willingness-to-pay for certain goods or services. The assumption is that among bidders information is symmetric (McAfee and McMillan, 1987). In real-life, such symmetry rarely exists and individuals often have additional private information (Rothkopf and Harstad, 1994). Typically, also among farmers there is variability in their knowledge of, and experience with different seeds (Kilwinger et al., 2020b; Subedi, 2003). Because a symmetry in information rarely exist in real-life, some studies have explored if the symmetric-bidders assumption can be relaxed (Güth et al., 2005; Pezanis-Christou, 1995; Maskin and Riley, 2000), that is, if results are still valid when this specific assumption does not hold. They affirmed that, especially in second price auctions, the dominant strategy remains to reveal one's true willingness-to-pay, i.e. bids represent bidders actual valuations (Güth et al., 2005; Pezanis-Christou, 1995; Rothkopf and Harstad, 1994).

In those studies that point out that the symmetric-bidders assumption can be relaxed, the objective is to just understand the valuation of a good or service. However, when the objective of the experimental auction is to understand the changes in valuation for goods or services upon provision of information itself, relaxing the assumption might be problematic. A first concern is that some participants already possess the information provided during the auctions that they are supposed to value. In that case a small or no increase in bids between the 'naive situation' and the 'informed situation' can have at least two main causes: 1) a buyer already possessed the information at the naive situation and based their value on this information, and 2) a buyer did not possess information at the naive situation, but had a low valuation for the information (Figure 1). A second concern is that participants might possess other information on benefits and drawbacks on which they base their bids than the information controlled for during

the auction. Drucker (2012) once said: "*the customer rarely buys what the company thinks it is selling him*.". This means that it cannot be assumed farmers base their bids only on the product traits on which information is provided.

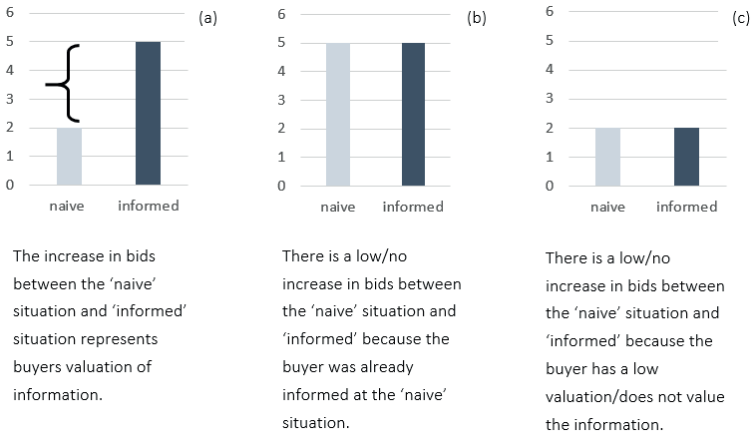


FIGURE 1. The increase in bids between the 'naive' and 'informed' situation represents buyers valuation of information (a). But can be the result of a bidder already being informed at the 'naive' situation (b) or a bidder having a low/no valuation for the information (c).

METHOD

Brief overview of the case study

To evaluate the usefulness of experimental auctions to understand smallholder farmers' demand for vegetative seed, we followed up on a Vickrey auction with Rwandan sweetpotato farmers in October 2019. Data was collected from a sub-sample of the total 29 auctions. In 3 different districts, 5 auctions in five different villages were selected. Apart from observing the auction event, the follow up consisted of post-auction interviews and a repertory grid analysis. The objective of the observations during the auctions was to gather information about the situation and interactions during the auctions. Aiming to find the meaning that participants attach to the study and trying to understand their behaviour, the interviews included questions on farmers' experience of the auction, motivations behind bids, product knowledge, and strategies

to develop bids. The repertory grid analysis was used to get a more thorough understanding of farmers product knowledge and preferred attributes that might have motivated their bids.

Approximately 24 farmers participated in each auction and the number of men and women who participated was stratified on the basis of village demographics. Invited farmers were selected from a validated census list of sweetpotato growers in the village. The auction was designed to estimate farmers' willingness-to-pay for 3 variables: genetic quality, physiologic/sanitary quality, and information. The first attribute, genetic quality, regarded an increased level of vitamin A. Farmers' valuation for this attribute was measured via the difference in willingness-to-pay for a local white or yellow fleshed variety and a so-called 'orange-fleshed-sweet-potato' (OFSP) variety. The second attribute, physiologic/sanitary quality, regarded clean seed sourced from a seed multiplier (quality seed). Farmers valuation for this attribute was measured via the difference in willingness-to-pay between farm-saved seed and seed from a multiplier. Combining those factors resulted in 3 products – of which two (P1 and P2) had been planted in demonstration trials in the villages where auctions were held:

- P1) vines of an improved Orange-Fleshed-Sweet-Potato (OFSP) variety, sourced from a seed multiplier
- P2) vines of an improved OFSP variety, sourced from a farmer
- P3) vines of a local variety, sourced from a farmer.

Before the actual auction started, a practice round was included with a familiar object, a soap bar, to ensure that the participants understood the auction. Thereafter the actual auction started. Next to measuring the values for the different products, the auction measured farmers' valuation of information, and hence included four bidding rounds. The first round was called the 'naive' round where no product information was provided. Before the second round, information on the benefits of material sourced from a seed multiplier was provided. Before the third round information on the benefits of the OFSP variety was provided. During the first three rounds, farmers could observe 8kg bundles of vines of each of the three products. Before the fourth round participants visited a demonstration plot to observe the difference performance of farm-saved seed

and seed from a multiplier of the OFSP varieties. During each bidding round, participants had to place bids in a sealed form for the 8kg bundles of vines. When the bids of all rounds were collected, a round and a product (bundle) were randomly selected. Whoever placed the highest bid in the selected round for the selected product, had to pay the second highest price with their own money. Endowments were purposively not provided to avoid the effect of 'house money' or 'windfall money'. For a more elaborate description of the auction procedure see Okumu et al. (2021).

Data collection and analysis

Observation of the auctions

Two researchers who observed the auction events had a list of specific topics they would observe: how farmers evaluated the vines and the demo trials, if farmers were discussing or trying to cooperate, how farmers reacted on the information the auctioneer provided, farmers' behaviour at the moment a buyer (winner) was selected, and the attitude of 'winning' farmers at the moment they had to pay. Any additional interesting or outstanding event was described. These researchers had no other tasks during the auction itself. Their observations resulted in a documented overview of each of the 5 auctions.

Semi-structured follow up interviews

After the observation of each auction, we approached farmers to participate in a follow-up interview. In 3 villages 12 farmers were interviewed and in 2 other villages 6 farmers were interviewed resulting in a total of 48 interviews (22 men and 26 women). The interviews were semi-structured and had questions about farmers' impression of the auction, their strategies, motivations, and previous experiences with the auctioned goods. The qualitative responses were coded and grouped based on similarities of the responses.

Repertory Grid Analysis

With a subsample of 18 farmers (6 from 3 different villages) the interview included additional questions for a repertory grid analysis (Kelly, 1955; Fransella et al., 2004). The repertory grid analysis allows respondents to select and verbalize personally relevant attributes they use to evaluate a good. During the interview respondents were

presented a 1kg bundle of each of the 3 auctioned types of sweetpotato vines, with labels indicating the variety and source (P1, P2 and P3). They were asked to group two products together which they believe are more similar to one another compared to the third. After grouping, respondents were asked why they considered those two products more similar. This resulted in a list of bi-polar attributes related to the products (e.g. has a high vitamin-A level – has a low vitamin-A level). Farmers were allowed to regroup the products based on other observed differences and similarities. When the respondent said (s)he could not mention more attributes they were asked which of the bi-polar attributes they preferred (e.g. "I prefer a high vitamin-A level"). After stating their preferences they were asked to rate the importance of each preferred attribute on a scale of 1 to 10, when they select sweetpotato vines. The attributes farmers mentioned during the repertory grid analysis were coded and grouped into overlapping categories.

RESULTS AND DISCUSSION

Farmers' monetary/economic valuation for vegetative seed

The concerns about farmers' willingness-to-pay being affected by the absence of references points and possible anchoring effects showed in the interviews. Of the 48 interviewed farmers who had participated in the auctions, 31 said they were not used to paying for sweetpotato vines. Among the farmers who are not used to paying, 13 said they are also not aware of the market price and could not estimate it. This raises the question why they had offered money in the auction for vines they could normally get for free. In addition, it shows the challenges for these farmers to come up with a reasonable reference price. One farmer said: "*I do not know the market price of sweetpotato vines because I never bought vines. My bids were just guesses as I tried to be in the game*".

Some farmers expressed in the follow up interviews that they faced challenges developing a bid because they did not bring (much) money to the auction, and hence were cash constrained. As a result, 10 farmers mentioned that their point of reference was 'the money they had in their pockets'. This information points to the need to

provide all participants with a cash endowment to use in the bidding. However, in the design phase of the experimental auction this alternative was dropped to avoid the undesirable windfall-effect as that might have contributed to the >0 price and overestimation of farmers' willingness-to-pay. Finding valuation mechanisms among participants who are cash constrained is a major experimental design challenge that requires further research.

Vegetative seed as economic good

The peculiar characteristics of vegetatively propagated seed also showed in the follow-up interviews. All interviewed farmers who won sweetpotato vines at the auction said they would provide fellow farmers with vines after they multiplied them. All the interviewed farmers who did not win the auction expected the winner would provide vines to fellow-farmers after having multiplied them. One farmer explained: *"I am not disappointed I did not win the auction because the winner is a neighbour and she will share the vines with me".* Because of these expectations, experimental auctions might at best measure the initial spike of market demand for attributes related to new genetic traits. It is unlikely that results reflect to a long-term demand: as more farmers are growing varieties with the new traits, it becomes easier and more likely that the farmers will acquire seed with the new attributes through an alternative route. The novelty of the traits forms not any longer a reason to purchase the seed.

In the long run, without introduction of new varieties the loss of seed quality over cycles of multiplication (seed degeneration) becomes a determining demand factor (Almekinders et al., 2019a). Regarding demand for quality seed, it can be expected that its utility depends on the difference in performance of farm-saved seed (Tripp, 2003). A consistent and predictable trend in seed degeneration can often not be observed in farmers' fields (Navarrete et al., 2022). In addition are there many other practices that farmers can apply to maintain seed quality besides acquiring new 'quality seeds' (Thomas-Sharma et al., 2017; Navarrete et al., 2022). Also in our case with sweetpotato vines, it was not self-evident that the auctioned quality seed outperformed the farm-saved seed that was presumably degenerated: in 3 of the 5 demonstration trials in the follow-up auction sites this was not the case. This created a difference between what

participants saw and what researchers advocate. Thus, the experimental auctions are unlikely to forecast the long-term demand for either genetic traits or quality seed of vegetatively propagated crops.

Furthermore, not only the characteristics of vegetative seed itself are relevant, but also the characteristics of the farmers who manage them. The experiment is constructed in such a way as if vines can only be obtained in a market place by exchanging them for money. Farmers' usual acquisition mechanisms are based on other economic principles such as a subsistence and reciprocal economies (Beumer et al., 2022). All participants came from the same community and engage with each other in these other types of economic activity, and as our interviews indicate, they expect they can obtain propagates of the auctioned vines via those mechanisms. How these other real-life economic mechanisms even further reflects into different decision-making outside the experimental context remains unknown.

We can argue that the characteristics of vegetatively propagated crops and its users come closer to those of common pool resources (Beumer et al., 2021) than the goods with a rather private nature experimental (Vickrey) auctions are generally designed for. A common-pool resource can be described as a shared resource that is governed by a community of users according to their rules and norms (Beumer et al., 2021; Bollier, 2014). Vegetative seed is not a unique indivisible object that can be sold to one potential user. Therefore vegetative seed obtained by a single community member not only has private value but also social value. This counts for both new varieties as they can be multiplied and distributed, and quality seed as the influx of clean seed can improve the overall health of the seed system.

Farmers make rational decisions, and their dominant strategy is to reveal true, maximum willingness-to-pay.

Vickrey auctions are said to be 'incentive compatible', which means that the participants' optimal bidding strategy is to reveal their true willingness-to-pay (box 1). Farmers are expected to construct an economic value for the auctioned vines in a rational and utility maximizing way, and are expected to do so on the basis of the same objective function (Mueller, 2004). When we asked farmers what their bidding

strategies were, we roughly identified three strategies: 1) to place a bid based on (perceived) market value, 2) to place a bid based on (in pocket) means and 3) to place (very) high bids. Some experimental design issues emerged that make rational behaviour and the display of an optimal bidding strategy that reveals true willingness-to-pay questionable. Many of those related to the fact that members of the same community are bidding against each other.

In farmer communities, seed exchange is typically heterogenous (Coomes et al., 2015). Farmers can be either or both providers and receivers of seed. Several studies have identified how social norms influence the way seed is exchanged in communities (e.g. Tadesse et al., 2017; Ricciardi, 2015; Subedi et al., 2003). Generally such studies find that 'better-off' farmers more often are seed providers, whereas more vulnerable 'poor' community members are more often seed receivers. Also during our follow-up interviews we identified several aspects that influence the flow of seed in the community (Table 1).

Table 1. The conditions under which farmers expected the auctioned material would be exchanged with others after multiplication (n=48). Farmers could give more than one answer.

Condition	n
Whether vines are exchanged with or without cash payment depends on the relationship between the farmers who exchange the seed. If they have a close and good relationship the vines will be provided without a cash payment.	15
When vines are exchanged this always involves a cash payment	11
Whether vines are exchanged with or without a cash payment depends on the initial way of acquisition. If the providing farmer paid to obtain the vines, the receiving farmer also has to pay for the vines.	8
Whether vines are exchanged with or without a cash payment depends on the social position of the providing farmer relative to the receiving farmer. If the receiving farmer is a more vulnerable community member the vines will be provided without a cash payment.	7
Whether the vines are exchanged with or without a cash payment depends on the abundancy of the exchanged variety in the area. If the variety is very scares, the receiving farmer has to pay for the vines.	4
When vines are exchanged they this never involves a cash payment	4

Farmers said they expected that propagates of the auction vines would be exchanged with fellow-farmers both with and/or without a cash payment. The majority of the farmers said that the relationship between the farmers exchanging vines determines if material has to be paid for or not. What further influences the conditions under which vines are exchanged is the initial way that providing farmer acquired the vines, the social position of the receiving farmer relative to the providing farmer, and the abundance of comparable vines in the area.

During the interviews, several farmers identified other bidders that were present in the auction as 'vine multipliers'. This suggests that farmers who are typically providers of seed where present at the auction and also gave their valuation. The participants' valuation of the seed with the underlying thought that in the future they are going to provide (sell) this seed, or will receive (buy) this seed, can lead to a different bidding strategies. A higher valuation will be in the interest of those who might sell it, whereas a low valuation is in the interest of those who might buy it. Several of our findings suggest it is not an unlikely scenario that farmers bid with the objective to influence future market prices. First, there were several farmers who said their strategy was to place high bids. Second, about half of the farmers understood the experimental auction as an event to determine the value farmers give to sweetpotato vines, and 12 farmers though it was to show there is a market for sweetpotato vines (Table 2). One farmer who won the auction in her village stated that she had placed a high bid and explained: *"I had a good impression of the auction as it showed the farmers that vines can be used as a business and should not be given away for free"*.

Not all farmers in the community who are regular providers of seed might have based their bids on the possibility to influence future market prices. Depending on the social norms and rules in the community, it might not be considered appropriate to request money when sharing seed with the less privileged community members. An example of the importance of social norms and values results from an observation made at one of the auctions. An elderly lady won the auction and was called to the front to buy the vines she won. With her head down she whispered she did not have money to pay for the vines. Secretly the seed multiplier (seller) handed her a bank note. She then used

this money to pay her vines in front of the group. This suggests that it is not only important to understand the social norms and values that influence the bidders/buyers behaviour, but also those that the seller is subject to. Social norms and informal rules seem to influence under which conditions a farmer can expect to acquire material, but also in which situation a provider request can for money and when is (s)he expected to provide material for free. The social norms and value lead to a bounded rationality, rather than the rationality that results in an economic market evaluation and assessment of willingness-to-pay for seed as meant by researchers. It demonstrates that rational choice is always embedded in moral choice, and cannot be understood outside of it (Streeck, 2010).

Table 2. Farmers' understanding of the purpose of the experimental auctions (n=48). Farmers could give more than one answer.

Purpose	n
The purpose of the auction was a form of training to teach about the benefits of orange-fleshed sweetpotato.	23
The purpose of the auction was a mechanisms to measure the value farmers give to sweetpotato vines	22
The purpose of the auction was a form of training to teach how to select sweetpotato vines.	20
The purpose of the auction was a form of training to promote sweetpotato vine multipliers	15
The purpose of the auction was to show there is a market for sweetpotato vines	12
The purpose of the auction was a form of training to teach how to improve sweetpotato production	6
The purpose of the auction was a form of training to teach how to properly multiply sweetpotato vines	4
The purpose of the auction was a form of training to teach how to run an auction	2

Another explanation for farmers who's strategy was to place high bids is to win the auction. This desire to win might be stronger when bids are made in front of groups

where a buyer (winner) is elected. One farmer said: *"I placed a bid of 3 times the market value because I wanted to win".* We also found the opposite reactions to the fact that the buyer (winner) had to make a payment for the vines in front of the group. Some farmers explained they were scared to be called to the front while being unable to pay for their material. To avoid this public humiliation they intentionally placed low bids. Those farmers made sure their bids did not exceed the money they had in their pockets and aimed to 'stay within their means'.

Finally, it seemed many farmers did not bid with the aim to obtain vines, but instead understood the event as a form of training (Table 2). If this was farmers understanding, giving a higher valuation for the products recommended by researchers makes sense. Researchers recommended vines from a seed multiplier over farm-saved seed because they are disease-free and therefore high-yielding. In the three auctions where the vines recommended by researchers did not yield higher in the demo plot, 83% of the interviewed farmers stated they still preferred the recommended product. Only 17% of those farmers motivated their preferences by a higher yield, and 71% because the material is disease-free. In the two auctions where the recommended vines did yield higher at the demo plots, all farmers stated they preferred this product. In contrast, the majority of those farmers (79%) motivated their preference by a higher yield, and only 26% because the material is disease-free.

The fact that many farmers understood the auction as a form of training can further be a reason that all farmers decided to bid and offer a >0 price (see Okumu et al., 2021 for the distributions of bids). Some quotes of farmers support this. One farmer said: "*Even though I did not have enough money to win I participated anyway, I just played the game and placed bids*", and another explained: "*I just participated in the auction, I was not really trying to win but I just placed bids. That is because I currently do not have a plot available*".

In sum, these findings give indications for non-standard beliefs, non-standard decision-making and non-standard preferences. Heterogeneity in the community might lead to non-standard beliefs as farmers bid with different objectives in mind. Farmers who expect to be future sellers of material likely have different utility functions than those

who expect they have to buy it. Furthermore did some farmers intentionally place very high bid for the sake of winning the auction whereas others placed low bids to avoid public humiliation. We identified several social and cultural norms that influence how sweetpotato vines are exchanged within the community. This can lead to non-standard decision making as farmers might base their decisions on those social and cultural norms rather than the principles of market economies. We also find indications that farmers based their preferences on the recommendations given by researchers. Therefore, farmers preferences might have been non-standard as they construct them for the experimental context.

Experimental auctions to measure how farmers value information.

In the auctions, the value of information on the genetic and physiological quality of the sweetpotato vines was measured. Researchers have information on specific benefits and drawbacks of sweetpotato vines, which farmers are expected to not have *ex ante* the auction. During the auction, farmers' willingness-to-pay (and preferences) were revealed in a 'naive' situation when farmers are assumed to be uninformed: they could only observe the sweetpotato vines. Farmers were subsequently provided with information on specific benefits and drawbacks of the auctioned vines.

Our interviews found that several farmers already had experience with both the improved OFSP variety as well as vines sourced from a seed multiplier. All farmers (n=48) knew and had been growing the local variety presented at the auction and made use of farm-saved seed. Many farmers (n=34) mentioned they already knew the improved OFSP variety and 25 of them said they were already growing it. Also many farmers (n=18) said they were already growing vines sourced from a seed multiplier. One women who won the auction explained she had participated in a training about OFSP vines: *"I knew the value of the product because I already grow it. OFSP vines were given to me by an NGO during a distribution which was accompanied by a small training".* Ten other farmers mentioned they have participated in some kind of training on OFSP vines before. The level of knowledge was hence not equal at the 'naive' bidding round. This makes it challenging to measure the value farmers gave to the provided information itself.

On another point related to the valuation of provided information was distilled from the repertory grid analysis. To estimate premium willingness-to-pay for specific product traits, all sellers should base their bids on these specific product traits. Because some farmers already had experience with the offered products, they might have had additional product information which they could use in their bidding. Eighteen farmers were interviewed with the repertory grid method to find out which attributes they associate to each product and hence might have motivated their bids. Combined, the farmers named 32 attributes when listing the differences between the auctioned vines (Appendix 3). Individually, farmers mentioned between 4 and 10 attributes with 7 on average.

Most farmers mentioned the 5 attributes on which information was provided during the auction: ‘Source’, ‘Variety’, ‘Vitamin-A level’, ‘Yield’ and ‘Diseases’. The other 27 attributes were based on farmers' own observations and experiences. Those attributes were related to the physical appearance of the material (e.g. shape, size and colour), agronomic characteristics (e.g. maturity time and adaptability to soil), and potential end uses (e.g. as vegetable and to make mandazi). Which of those product traits was preferred also differed among farmers. The promoted OFSP variety attributes were Vitamin-A and a high yield, whereas earlier studies have shown that OFSP varieties are adopted because of their sweet taste and dry matter content (Adekambi et al., 2020; Mwiti et al., 2020). Famers who have previous experience with OFSP might have based their bids on for example those traits instead of only those promoted at the auction.

CONCLUSIONS

This paper explores the validity and usefulness of Vickrey auctions when applied to understand farmers valuation of vegetative seed. We make a contribution to understanding decision-making behaviour via a follow-up interviewing of Rwandan smallholder farmers who participated in an auction about their experiences, strategies and beliefs. Validity refers to the extent to which a measurement instrument actually measures what it purports to measure. Therefore, the object of measurement should be clarified. Experimental auctions are used to answer different research questions that

have the objective to measure preferences, willingness-to-pay, willingness-to-pay premiums, demand, relative demand, the effectiveness of interventions, and predict future behaviour. We find that certain assumptions may be violated in this specific research contexts, and that depending on the precise objective of the auctions this might affect the validity and usefulness of Vickrey auctions.

Vickrey auctions can be used to estimate the monetary value people place on non-market goods, or goods circulating in imperfect markets. Because of farmers' current seed sourcing practices, prices of comparable products that can be used as a reference might be absent. Several farmers expressed they did not know the market value of sweetpotato vines and had difficulty giving an estimation. In such situations it is relevant to explore what peoples reference prices are and whether an anchoring effect occurred. For example, during our follow-up study some farmers said their point of references was the money they had in their pocket. This might lower validity of the results if the magnitude of bids is used to develop future pricing policies. When results are only used to understand farmers preferences or relative demand among different seeds this is less problematic. Even with small amounts of available cash farmers can express their preference by placing a higher bid for preferred products.

Vickrey auctions can also be used to understand if a market for a good exists. We find that farmers are likely to continue multiplying and sharing sweetpotato vines based on social norms and values. This is possible because vegetative seeds are reproducible while maintaining the genetic quality and these practices are likely to be sustained as long as there are no serious seed degeneration affecting the quality of the planting materials. Auctions measuring the demand for a new variety likely only measure the initial spike of demand, before this variety gets absorbed in the informal seed system. This lowers ability of auctions to predict future and long-term demand for seed.

The way the experimental auction context differs from real-life might affect the external validity of auction results. The auction experiment we studied was constructed in such a way as if vines could only be obtained in a market place by exchanging them for money. In real-life, alternatives to purchasing vegetative seed are usually present. We found indications that this influences the way farmers constructed their valued

during the experiment. Because all participants come from the same community and engage with each other in several types of economic mechanisms (e.g. subsistence, reciprocity), they expect they can obtain the auctioned vines via those mechanisms. Furthermore, there were indications that farmers objectives during the auction differed, that their decisions were based on social norms and values, and that preferences might have been constructed for the experimental context as many farmers understood it as a training event. On one hand this indicates that the experimental auction design is as realistic as possible by working with participants' own expected benefits, constraint and preferences. On the other hand, it affects the validity and usefulness of the auction for predicting long-term market and business perspectives for seed as a commercial good.

Vickrey auctions can be useful to understand farmers preferences and how farmers valuation for seed changes under different conditions. Results can be used to define if future interventions, for example extension services providing information seed quality, would be successful. We find that farmers had variable knowledge of the auctioned products prior to the auction, used different attributes to evaluate the products, and differ in their preferences for those attributes. If farmers' knowledge levels prior to the information provision are varying and unknown, it is problematic to measure how they valued the information itself. Furthermore can it not be confirmed they based their bids only on the information that the experiment controlled for.

In sum, farmers' decision making towards (vegetative) seed in real life seems far more complex than what can be captured in the experimental context when only bids are correlated with demographic information. The fact that farmers are, as Ellis (1993) stated 'with one foot in subsistence and with the other in the market' makes it extremely challenging to design auction experiments to understand farmers' decision making that have a high external and predictive validity.

We conclude that experimental (Vickrey) auctions are an interesting addition to the researchers' toolbox to understand smallholder farmers' valuation of seeds that are vegetatively or otherwise multiplied and shared in imperfect market situations. Experimental auctions have several benefits as they i) attach real economic

consequences, ii) embed realistic conditions and iii) can measure how demand changes in different conditions. Nevertheless, we pointed out several methodological issues that have to be resolved to increase the validity of these measurement in this specific research context.

We would like to see our findings validated in other crops and situations, since understanding demand for seed in different contexts is much needed to improve seed provisioning for smallholder farmers (Mausch et al., 2021; McEwan et al., 2021). In situations where farmers more commercially access seed for every planting, f.e. for hybrid maize and vegetable seeds, the experimental Vickery auctions could more closely reflect a real life willingness-to-pay than in a vegetatively propagated subsistence crop like sweetpotato in Rwanda. We also would like to explore how experimental auction settings can be adapted or complemented with other types of data collection to better understanding of real-life purchasing decisions. Furthermore would it be interesting in this context to explore what outcomes are generated with economic valuation methods designed for commons or public goods. Such methods could be used to understand the value for clean seed on the community level instead of on the individual level. The use of clean seed does not always have a direct clear individual benefit in terms of yield gain. A continuous influx of clean seed can however have a value at a community level as it prevents the acceleration of spreads of pests and diseases by farmer-to-farmer seed exchange.

CHAPTER
Six

Methodological considerations on the means-end chain analysis revisited

Publication information

Adapted version of: Kilwinger F and van Dam Y. (2021). Methodological considerations on the means-end chain analysis revisited. Psychology & Marketing, 38(9), 1513-1524.

ABSTRACT

Means-end chain analysis has been applied in a wide range of disciplines to understand consumer behavior. Despite its widespread acceptance there is no standardized method to analyze data. The effects of different analyses on the results are largely unknown. This paper makes a contribution to the methodological debate by comparing different ways to analyze means-end chain data. We find that (1) a construct that is not mentioned can still be important to a respondent; (2) coding constructs at the same basic level or condensing constructs at a superordinate level lead to different results and both an increase and decrease of information; (3) aggregating data can be based on different algorithms which influences the results. Among available software packages there is no consistency in the used algorithm; (4) before applying means-end chain analysis in a new research area the validity of assumptions underlying the research model should be evaluated. We conclude there is no universal "best way" to means-end chain analysis, the most suitable approach depends on the research question. Research concerning how products are evaluated can best apply number-of-respondents-based aggregation and low levels of condensation. Research concerning why products are valued can best apply frequency- of-responses-based aggregation and high levels of condensation.

INTRODUCTION

The means-end chain model and related laddering methodology were developed in the 1980s to understand not only how, but also why, consumers value products or services (Grunert & Grunert, 1995; Gutman, 1982; Reynolds & Gutman, 1988). Since its development, the method has been widely used to gain insight into consumers' product knowledge and motives for product choice (Anastasiadis & van Dam, 2014; Costa et al., 2007; Merfeld et al., 2019; Reynolds & Phillips, 2009). Means-end chain theory is based on several influential theories in psychology (Reynolds & Olson, 2001), such as personal construct theory (Kelly, 1955), attribute theory and cognitive structure (Scott, 1969), and human values (Rokeach, 1973). Means-end chain analysis allows marketing problems to be framed and analyzed as consumer decisions. In means-end chain analysis, qualitative data are transformed into quantitative results which tends to have high levels of appeal for marketing research. Consequently many applications of means-end chain analysis are found in market research covering product development and evaluation (Costa et al., 2004; Patrick & Xu, 2018; Reynolds & Phillips, 2009), advertising (Bech-Larsen, 2001; Eberhard, 2017), and market segmentation (Grunert, 2019; Pezeshki et al., 2019; Ter Hofstede et al., 1999).

Means-end chain analysis is an umbrella term for several related methodological parts. In combination with its application in several research fields, this has resulted in haphazard development of its theoretical and methodological underpinnings (Grunert et al., 2001; Reynolds & Olson, 2001). Numerous methodological papers have appeared that focus on specific aspects of means-end chain analysis such as the merits of different attribute elicitation techniques (e.g., Bech-Larsen & Nielsen, 1999; Steenkamp & Van Trijp, 1997), the differences between hard and soft laddering (e.g., Grunert & Grunert, 1995; Phillips & Reynolds, 2009; Ter Hofstede et al., 1998), the determination of a suitable cut-off level (e.g., Bagozzi & Dabholkar, 1994; Grunert & Grunert, 1995; Reynolds & Gutman, 2001), different techniques to analyze and report the aggregated results (e.g., Aurifeille & Valette- Florence, 1995; Fu & Wu, 2013; Gengler et al., 1995; Kaciak & Cullen, 2006; Leppard et al., 2003; Ter Hofstede et al., 1998; Valette- Florence & Rapacchi, 1991), or the interpretation of the results (e.g.,

Grunert & Grunert, 1995; Olson & Reynolds, 2001). These explorations of specific methodological aspects have not resulted in a complete and formalized means-end theory that supports a single methodology (Olson & Reynolds, 2001; van Rekom & Wierenga, 2007). As a result, the means- end approach lacks a clearly specified theoretical foundation, limiting its appeal to academic scholars in consumer research (Grunert, 2010; Reynolds & Olson, 2001).

Despite the lack of a clear theoretical foundation, application of means-end chain analysis has spread to new domains since the turn of the century. Examples are tourism, agriculture, and user experience studies (e.g., Klenosky, 2002; Lagerkvist et al., 2012; Vanden Abeele et al., 2012). This application of means-end chain analysis in new research areas is generating novel methodological complications. For example, in user experience studies less elaborated ladders that contain comparatively more attributes and less values are typically elicited, which requires a tailored analysis (Vanden Abeele & Zaman, 2009; Vanden Abeele et al., 2012). LADDERUX software was developed to improve the reliability and validity of means-end chain analysis for these user experience studies.

In this paper, we will address methodological difficulties that were encountered while applying means-end chain analysis in a smallholder context in Uganda. The findings of this study contribute to the theoretical understanding of means-end chain analysis and consumer psychology in general, as well as the identification of methodological implications when applied among smallholder farmers. We will start with a brief overview of the method and the debates around its different steps. Thereafter we will make a contribution to the debate based on application of means-end chain analysis to understand smallholder farmers' decision making. We analyze in detail a case study conducted among Ugandan banana farmers, and in addition draw upon literature of other studies conducted among smallholder farmers aiming to understand their choices on seed selection. The results and discussion focus on 4 main issues:

1. Attribute elicitation and why important attributes might not be elicited.
2. Coding and the difference between coding and condensing.

3. Aggregating results and the difference between algorithms based on frequency-of-responses and algorithms based on number-of- respondents.
4. Application in a new research area and methodological considerations.

Means-end chain analysis

Means-end chain analysis refers to a set of techniques for interviewing individual consumers about the reasons for their product choice and interpreting consumers' responses in terms of generalizable linkages between outcomes (Olson & Reynolds, 2001). Means-end chain analysis is firmly based in the pragmatic and functionalist marketing tradition (Alderson, 1957; Brown, 2002; Dixon & Wilkinson, 1984). This tradition builds on the assumption that all people construct a mental representation for making sense of and acting upon the world they experience (Brunswik, 1943; Kelly, 1955). This personal mental representation consists of a web of functional associations and informal hypotheses that predict personally relevant consequences from observable cues (Neisser, 1976; Peirce, 1878; Tolman & Brunswik, 1935). In this web of constructs the products that people purchase are bundles of functionalities that they can use (Lancaster, 1966; Rosen, 1974). People prefer and select products for the consequences that these products (are expected to) provide, and for the goals that these consequences help to achieve (Vargo & Lusch, 2004). Because people have different skills and aptitudes, and because people live in different circumstances and contexts, they perceive different relations between observed attributes, inferred consequences, and valued goals (Jan et al., 2012; Peach & Constantin, 1972; Storkerson, 2010; Tolman & Brunswik, 1935; Zimmermann, 1933). Means-end chain analysis accommodates these individual differences by inviting individual respondents to select and verbalize their own constructs to describe how products are linked to their personal goals (Walker & Olson, 1991).

Beyond the domain of consumer marketing means-end chain analysis has been applied to, for example, business research (Inoue et al., 2017), organizational research (Bourne & Jenkins, 2005; Ronda et al., 2018), and project management (Verburg et al., 2013). Recently means-end chain analysis is also recognized as a promising tool to better understand farmers' motivations for the adoption or nonadoption of novel agricultural

practices or technologies (e.g., Lagerkvist et al., 2012; Ngigi et al., 2018; Okello et al., 2019; Salame et al., 2016; Urrea- Hernandez et al., 2016). In these different applications the core purpose of the analysis has remained unchanged over time: to explore the implicit product knowledge and personal motives of respondents that explain the choice for one course of action over another. This notwithstanding in any study each individual laddering interview only can cover part of each respondent's cognitive or motivational web of sense-making (Grunert & Grunert, 1995). To generate a valid shared web of sense-making the results of laddering interviews therefore have to be aggregated across respondents.

Collection and aggregation of means-end chain data

A means-end chain analysis starts with the elicitation of personally relevant attributes that a respondent uses to evaluate a product or service. Starting from these elicited attributes individual interviews uncover the relations between the (physical) features and attributes of products and their (psychologically) valued consequences (Reynolds & Gutman, 1988; Reynolds & Phillips, 2009). This is done by repeatedly asking the respondent "*why is it important to you that…"* which results in a personally relevant sequence of attributes, consequences, and values referred to as "ladders." These interviews, commonly referred to as laddering interviews, cover each elicited attribute of the respondent.

Once the data have been collected for individual respondents, the analysis follows three steps (Aurifeille & Valette-Florence, 1995; Gengler et al., 1995; Grunert & Grunert, 1995; Reynolds & Gutman, 1988). First, a content analysis is performed and comparable constructs of individual ladders are coded into common denominators. Second, the linkages between coded constructs in the ladders are aggregated across respondents in an implication matrix. Third, the aggregated associations between attributes, consequences, and values are represented graphically in a hierarchical value map. This hierarchical value map is made comprehensible and readable by deleting incidental and redundant linkages, allowing a focus on the dominant means-end chains. The distinction between "dominant" and "incidental" is determined by the researcher

by selecting a cut-off level. Linkages that occur less than the selected cut- off level are not presented in the hierarchical value map.

In the aggregated hierarchical value map the dominance of a specific means-end chain should depend on a frequency and a representativeness criterion, i.e. the number of individual ladders that are represented by that chain and the accuracy of that representation (Aurifeille & Valette-Florence, 1995). Among the three steps coding is the most cumbersome, and iterative coding may be required before a satisfactory balance between representativeness and manageability is achieved (Grunert et al., 2001). Once the coding has been performed, the actual aggregation is usually considered uncomplicated but time consuming. Therefore several computer software programs have been developed, like LADDERUX, MECANALYST, or LADDERMAP, that transform ladders into hierarchical value maps (Lastovicka, 1995; Naspetti & Zanoli, 2004; Vanden Abeele et al., 2012).

METHOD

A means-end chain analysis was conducted among Ugandan farmers to understand choice for supplier of banana planting material. Data were collected in interviews with 31 banana farmers during November, 2017. Apart from collecting demographic and production information, the interviews consisted of two parts: attribute elicitation and laddering. Data were collected by five interviewers who had received a two-day training to conduct the interviews.

Attribute elicitation

Attributes were elicited by triadic sorting following the repertory grid method (Kelly, 1955). The respondents (farmers) were presented with triplets of cards, with a different source for banana planting material written on each. In total nine different sources for banana planting material were offered, representing a range of formal and informal channels: a laboratory, a nursery, the National Agricultural Advisory Services (NAADS), the National Agricultural Research Organisation (NARO), a Non-Governmental Organisation (NGO), a large-scale farmer, a remote farmer, a neighbor

and the own farm. Each respondent was presented with nine pre-defined triplets of cards. For each triplet of cards respondents were asked to group two sources which appear similar to them as opposed to the other. While doing so the respondents were given the following scenario: Imagine you have to source banana planting material for the coming planting season.

> *"I now present you with three seed sources where you could source this planting material. Which two seed sources have, according to you, more similarities as opposed to the other?"*

After grouping a triplet of seed sources each respondent was asked to describe why these two where similar compared with the other one. This was repeated for each triplet, resulting in a list of bi- polar word pairs. Next the bi-polar word pairs were listed, and for each word pair the respondent was asked which of the two was preferred. This resulted in a list of preferred "constructs" and nonpreferred "contrasts."

Laddering

The soft laddering method (Grunert & Grunert, 1995) was used to elicit individual means-end chains using the elicited constructs as starting attributes. Soft laddering is the recommended technique in studies with a relatively small sample size (<50) and of an exploratory nature (Costa et al., 2004). Starting from each preferred construct a series of "*Why is it important to you that…"* questions were asked until the respondent reached a dead end. Means-end chain theory postulates that in this asking a ladder of constructs is created. If more than one reason for importance was given to a construct, each of these were explored further and a forked ladder of constructs was created. It was emphasized to the respondents that there were no right or wrong answers and that the aim of the interview was to understand their individual preferences.

Coding

After conducting all the interviews, the constructs mentioned in the ladders were coded. Coding was done by two researchers independently. In cases of inconsistencies, the team discussed which code was most suitable using transcripts of the original interviews. The main purpose of coding is to enable aggregation of responses across

individual respondents, but guidelines for this aggregation are notoriously vague. Coding should be broad enough to obtain replications "across more than one respondent" but not so broad as to lose "too much" meaning (Reynolds & Gutman, 1988). To compare the effect of "the level of condensation" on the results, contrasting constructs (e.g., "dark peel" and "light peel") were both grouped, and not grouped, into a superordinate construct (e.g., "peel color").

Constructing the hierarchical value map

After coding an implication matrix was constructed to create means-end chains by aggregating the ladders across all respondents. From the implication matrix, a hierarchical value map was created to graphically present these aggregated means-end chains. For the construction of the implication matrix and hierarchical value map two algorithms were used. The first algorithm aggregated the frequency (f) of direct and indirect linkages between constructs to arrive at the implication matrix. If the same respondent repeated a linkage between the same two constructs in different ladders, each appearance of this linkage was counted in the implication matrix. The second algorithm aggregated the number-of-respondents (n) making direct and indirect linkages between constructs to arrive at the implication matrix. If the same respondent made a linkage between two constructs multiple times, the linkage was only counted once in the implication matrix. Both algorithms are commonly used in existing research.

The cut-off levels to be used for the construction of the Hierarchical Value Map (HVM) should create an informative but clear picture (Reynolds & Gutman, 1988). A more formalized way of deciding on a cut-off level has so far not been agreed upon in literature (Costa et al., 2004). For the comparison of the two algorithms the cut-off levels were chosen in two different ways. First the cut-of level of the frequency-based hierarchical value map (f-HVM) and the number of respondent-based hierarchical vale map (n-HVM) were chosen to represent approximately the same percentage of the total established linkages. Next the cut-off level of the n-HVM was set at the same absolute value as the f-HVM.

RESULTS AND DISCUSSION

Why attributes are elicited or not

Attribute elicitation, for which several methods are available, forms the basis of means-end chain analysis. Attributes can be classified along three dimensions of importance: salience, relevance, and determinance. Salience reflects the ease at which attributes come to mind, relevance reflects the degree to which an attribute is linked to personal or social values, and determinance reflects the importance of an attribute in judgment and choice (Van Ittersum et al., 2007; van Dam & van Trijp, 2013). Different elicitation techniques lead to different sets of attributes (e.g., Bech-Larsen & Nielsen, 1999; Steenkamp & Van Trijp, 1997; Van Ittersum et al., 2007). In addition to the elicitation technique, attribute elicitation is dependent on the product-use situation (Fransella et al., 2004). The product-use situation modifies the relevance of consequences for that particular situation. Therefore respondents must be provided with a scenario describing the particular product-use situation before starting the elicitation task.

It is known that different elicitation techniques lead to a different set of attributes, and that the product-use situation has an influence on the elicited attributes. This notwithstanding we want to introduce a new consideration on differences in elicited attributes. This consideration is especially relevant when means-end chain analysis is used to compare different groups of consumers, where the method of attribute elicitation and product use situation are kept constant. Means-end chain analysis draws from multiple psychological theories, which means results can be interpreted in multiple ways. A main underlying assumption is that while making choices, consumers create categories based on cognitive distinctions. *"Distinctions are dichotomies that represent the end points of dimensions along which objects may be compared"* (Gutman, 1982, p. 63). How consumers group products or services in different categories depends on which features they emphasize and ignore (Gutman, 1982).

One concept that means-end chain theory uses to explain those features people use in their evaluation is motivation (Mort & Rose, 2004). Personal values represent an individual's goals, desires, or aspirations and motivate decisions and actions (Okello et al., 2018). The concept of motivation is linked to probabilistic functionalism:

behavioral motivation to consume is based on how product knowledge is related to self-knowledge. Attributes are thus selected for the consequences they are expected to provide, that help achieve personal values. Probabilistic functionalism plays a central role in the personal construct theory. The personal construct theory implies that a construct only is convenient for the anticipation of a finite range of events.

The objective of means-end chain analysis is to explore the implicit product knowledge and personal motives of respondents that explain the choice for one course of action over another. But when a certain chain of constructs does not appear, is that due to a lack of motivation, a lack of product knowledge, or because it's not in the range of convenience? For example: when the hierarchical value maps of two groups of farmers are compared, the following difference might emerge: group A relates “low pesticide use” to “save money” and “better for health,” group B relates “low pesticide use” to “save money” alone. Based on the above named theories, how should these results be interpreted? Based on the concept of motivation, health might be more important for one group providing the motivation to reduce pesticide use. Based on probabilistic functionalism, one group might be aware of the negative side effects on health and reduces pesticide use, whereas the other group is not aware of those negative side effects. And based on the personal construct theories' range corollary, one group of farmers could be organic producers that do not consider the level of pesticides use at all as pesticides are outside their range of convenience.

These different possibilities make interpretation of means-end chain data complicated. Moreover motivations, experiences, and ranges of convenience can change over time. For example, subconscious motivations can be activated by goal priming (Okello et al., 2018). Experience and learning are cyclic, therefore a person's knowledge and believes can constantly be adapted (Kelly, 1955). Ranges of convenience can change based on a person's openness to increase the range (Kelly, 1955), for example when a conventional farmer shifts to organic farming practices. The interpretation that some features are emphasized by one group and ignored by another might thus be too simplistic and can result in misunderstanding. It is important that researchers are aware

of these differences when interpretating their data. To make an adequate interpretation, profound understanding of the researched population is essential.

Coding and condensing

In means-end chain interviews respondents create ladders using their own verbalizations. Different respondents use different words for similar constructs and this requires coding to enable aggregation of responses across respondents. To be able to aggregate responses, constructs must be coded into common denominators, thereby reducing the number of unique ladders. Responses such as "…will generate a higher yield" and "…will increase the production" can be coded into "increase yield." To a large extent coding determines the outcomes of the research. Propper coding is a most complicated step in means-end chain analysis because of unresolved theoretical issues (Grunert et al., 2001). Broad coding reduces the number of constructs to manageable proportions but result in loss of meaning whereas narrow coding preserves meaning but results in high numbers of constructs that are cut-off and lost afterwards (Grunert et al., 2001; Reynolds & Gutman, 2001). Resolving this methodological conflict requires the consideration of theoretical issues. We discuss three issues regarding coding where means-end chain analysis diverges from the underlying personal construct theory.

One assumption that means-end chain analysis adopted from personal constructs theory is that respondents perceive the world in dichotomies. In means-end chain analysis these dichotomies imply that perceived distinctions indicate the end points of a dimension along which objects may be compared (Gutman, 1982). When respondents make a dichotomy they are requested to state their preference to one of the end points of this dimension. This preference forms the starting point of the laddering interviews. In personal construct psychology dichotomous perception implies that constructs are bipolar and each construct implies a contrast. Each evaluation simultaneously affirms and denies, because perceiving something implies perceiving something as not its contrast. Often the opposite pole of a personal construct gives us a clear meaning of that construct. This bipolarity does not imply that the underlying dimension is dichotomous, because different pairwise comparisons may imply a range of possible

evaluations on a single dimension (Fransella et al., 2004). For example respondents perceive a large- scale farmer to be "located far away" when compared with a neighbor. The same large-scale farmer is perceived "located close by" when compared with a nursery (Kilwinger et al., 2020b). "Far away" and "close by" is an axis of reference, so that elements which in one context are "far away," in another context become "close by." Respondents' preferences on such a ranged dimension may be at any ideal point, rather than at one of the end-points (Huber, 1976; Moore, 1982). Both in coding and in the interpretation of aggregated responses it must be clear that a preference in a specific direction does not imply that "more is better" indefinitely.

A second assumption that means-end chain theory adopted from personal constructs theory is that these dichotomous constructs are organized hierarchically. In means-end chain theory the hierarchical ordering implies that all associations express causality, as an attribute causes to a consequence and a consequence causes a value (Grunert et al., 2001). People distinguish between product attributes causing desired and undesired consequences, and the prefer the former. Thus farmers prefer a "round shape" of seed potatoes because round seed potatoes cause a "high yield" (Okello et al., 2018). In personal construct theory the hierarchical order of construct refers to two noncausal types of ordering (Fransella et al., 2004; Mirman et al., 2017). One type of ordering creates an abstraction that transcends the construct-contrast distinction. A subordinate bipolar dimension becomes one end pole of a superordinate dimension. This condenses information taxonomically and logically (Wierzbicka, 1984; Yee, 2019). The construct potato is superordinate to a range of distinct varieties and species, and subordinate to the nightshade family. Likewise the shape of a potato is superordinate to round and oval and subordinate to the appearance of the potato. The other type of ordering creates a clarification by thematic extension within a given context. This enriches information by invoking subjective associative knowledge (Neisser, 1976; Plant & Stanton, 2013; Ratneshwar et al., 2001). Thus new varieties of seed potato from a formal seed developer can be associated with higher yields and a rounder shape compared with traditional varieties.

Now we have described that the hierarchical assumption differs between personal construct theory and means-end chain theory we want to introduce the distinction between coding and condensing. The purpose of coding in means-end chain analysis is to allow aggregation of responses given in own words by grouping them into a common denominator. This is often confused with what we call condensing which is grouping subordinate constructs into a superordinate construct. For example Grunert et al. (2001) state that "tastes great" and "excellent taste" can be coded into "good taste," and that "good taste" and "bad taste" can in turn be coded into "taste." The number of constructs can be reduced by grouping subordinate constructs into a superordinate denominator, but attributes are coded into attributes and consequences into consequences. The superordinate code should also maintain the valence of a construct. The information on how the preferred consequences are related to distinct product attributes is lost when subordinate constructs are condensed into a superordinate construct. Coding (or rather condensing) should hence maintain the right level of abstraction of a construct.

Grunert et al. (2001) therefore argue that each step that makes coding more "condensed" leads to a loss of information due to increased abstractness. This notwithstanding the abstracting hierarchy can provide a more general insight in systemic relations that are independent of personal preferences. This is important if different respondents express a preference for opposing poles of a dimension, or if they use distinct related dimensions, like shape and color, for the same end. Condensed coding for abstraction can show that, despite individual differences, farmers generally use "appearance" of seed material to evaluate quality (Okello et al., 2018; Urrea-Hernandez et al., 2016).

To illustrate this we condensed our coding by grouping dichotomous constructs into a superordinate construct, for example, "improved cultivar" and "traditional cultivar" into "cultivar type." This reduced the number of concrete attributes presented in the HVM from 10 to 8 but adds two new abstract attributes (Figure 1). The newly appearing constructs relate "cultivar type" to "adaptability to environment" and "disease resistance." This adds information to the value map that adaptability and

disease resistance are important to farmers and depend on the cultivar type (Figure 1a). It does not provide the information that apparently there is no consensus among farmers about the type of cultivar that provides these consequences. In addition it does result in a loss of information that "traditional cultivars" are preferred because they have a "good taste" and a "long lifespan," whereas "improved cultivars" are valued because of their "big bunches" (Figure 1b).

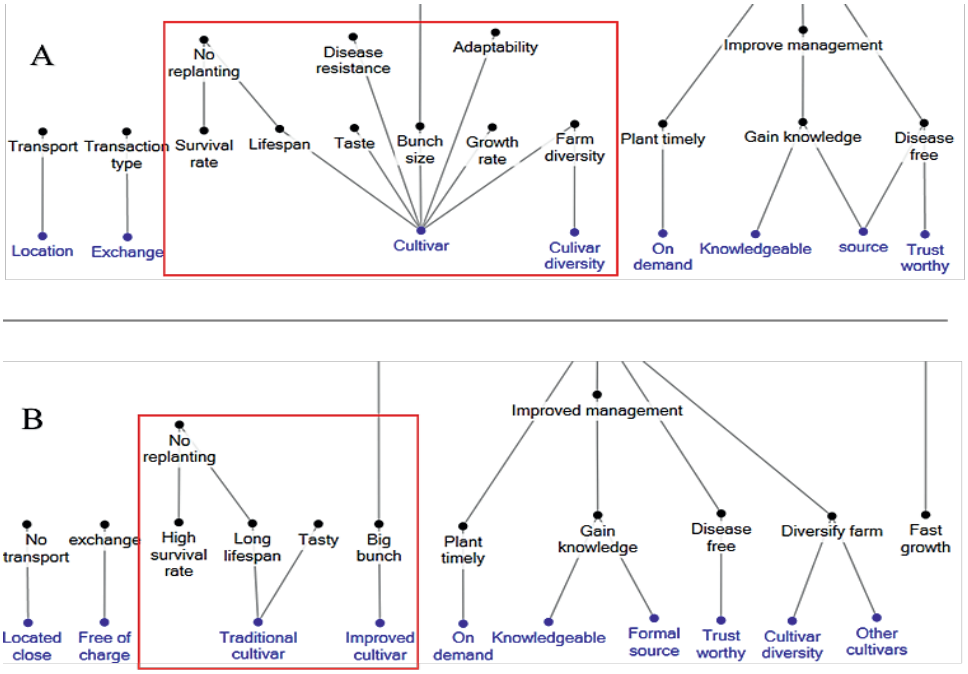


FIGURE 1. Effect of coding by (a) condensing, and (b) not condensing subordinate constructs. Concrete attributes are presented in blue. The red square highlights the effect of condensing the attribute 'cultivar'.

Condensing subordinate constructs can thus result in both an increase and a loss of information at the same time. This makes it hard to argue which method might be better as this depends on the research question. It is at least important that researchers are aware that "coding" responses given in own words into common denominators is different than "condensing" responses in a superordinate denominator, know the consequences of condensing on their results, make informed decisions, and apply a consistent level of condensation on their data set. When researchers are not consistent this might lead to a skewed understanding of differences between consumer groups. In

sum we have discussed here three issues of coding that have not been described clearly in literature and might be confusing: (a) dichotomous constructs ≠ bipolar constructs, (b) hierarchical relation of constructs ≠ hierarchical order of constructs, (c) coding responses ≠ condensing responses.

Coding and condensing are cumbersome tasks that require expertise and greatly influence the results of the study. To avoid biases, there could be a future role for text analysis software (such as specific R studio packages like "tidytext" or Atlas TI). Such software is capable of systematically analyzing text and can store responses at different levels of "condensation," starting at the original statement to abstract constructs. Further research is needed to explore the accuracy of such software compared with manual coding and condensing.

Transforming individual ladders into means-end chains

After all the elicited constructs have been coded, the links between constructs made in the individual ladders can be aggregated in an implication matrix. In this step, the qualitative data is transformed into quantitative data. This implication matrix should display "the number of times each element leads to each other element" (Reynolds & Gutman, 1988). This can be interpreted in several ways. For example, both direct and indirect linkages can be counted in the implication matrix. Another possibility is to count the number of times elements are linked or the number of respondents that link elements. In laddering interviews, the implicit knowledge and understanding of each respondent is made explicit by linking concrete attributes through abstract attributes, functional consequences, psychosocial consequences, and instrumental values to terminal values (Walker & Olson, 1991). Whenever different concrete attributes link to a similar higher level construct, which is likely to happen after coding, all subsequent linkages can be duplicated in the interview. This increases the frequency in which linkages between the (higher level) constructs are mentioned but not the number of respondents who mention them. The number of respondents who mention a linkage across interviews indicates the dominance of the linked constructs, and the representativeness of that linkage, in the population (Valette-Florence & Rapacchi, 1991).

Apart from common linkages that are shared with others, people will have unique individual sets of constructs and linkages due to their individual differences in circumstances, skills, and aptitudes. Counting the frequencies of linkages across and within respondents or counting the numbers of respondents making the same linkage therefore will lead to different outcomes. Number-of-respondent- based aggregation favors dominance of commonly shared linkages in the population and tends to ignore context-specific individual linkages. Frequency-based aggregation favors individually dominant linkages relative to commonly shared linkages. The study of consumer behavior can historically be divided in two perspectives: the idiographic and nomothetic. The idiographic perspective aims to find explanations for behavior that are individual-specific. The nomothetic perspective aims to find universal principals of behavior across individuals (Bagozzi & Dabholkar, 2000). Frequency-of-responses-based aggregation seems to fit the former perspective and number- of-responses the latter.

Both counting frequencies and number-of-respondents have been converted into algorithms that are commonly used for data aggregation. Among laddering software the program LADDERMAP counts numbers and construes an implication matrix "such that, though a given respondent may repeat the associations between the same cognitions several times in several ladders, the association between cognitions is tabulated only once per subject" (Lastovicka, 1995, p. 495). The software program LADDERUX on the other hand counts frequencies and construes an implication matrix from the frequency with which an association is mentioned across multiple ladders within and across respondents (Vanden Abeele et al., 2012). MECANALYST provides both options and the manual states that: "if a synonym is repeated a number of times in the same subject/ladder, then this can be ignored by selecting "Use single links in same subject/ladder" or taken into account by selecting "Use multiple links in same subject/ladder." Normally, the single links option should be checked for both subject and ladder to prevent the results from being biased by garrulous interviews. But in some instances you may want to choose a different option" ("MECAnalyst user guide," s.d., pp. 31–32).

The choice of algorithm for aggregation will affect the results of a means-end chain analysis in the hierarchical value map. When results are presented with a cut-off level of 1, all linkages are represented by both algorithms, but frequency-based aggregation will give higher weights to linkages that are repeated in a single interview. When results are presented with an absolute cut-off level higher than 1, the number-based aggregation will represent a subset of linkages compared with the frequency-based aggregation, because the latter will also show linkages that are mentioned several times (over cut-off) by a few (under cut-off) respondents. A frequency- based algorithm implies higher numbers of observations for linkages compared with a number-based algorithm and therefore requires a higher cut-off level to maintain readability. Once different cut-off levels are used for number-based and frequency-based aggregation, even if a similar fraction of linkages is represented the resulting hierarchical value maps will no longer overlap. This notwithstanding, the vast majority of research papers do not explain by which algorithm the implication matrix is construed, even if the software used is mentioned, nor whether the aggregated numbers in the implication matrix refer to frequencies of linkages or number of respondents mentioning the linkage.

After coding our own data set a total of 88 constructs remained of which 40 were classified as attributes, 24 as consequences, and 25 as personal values. The aggregated implication matrix resulted in a total of 420 different direct linkages between 88 constructs (Table 1). Most of these linkages only appeared once (47%) or were made by only one respondent (60%).

Table 1. Number of direct linkages that would appear at a cut-off level between 2 and 7 for frequency-based hierarchical value maps (*f*-HVM) and number-based hierarchical value maps (n-HVM)(n=31).

Cut-off level	Number of direct linkages *f*-HVM	% of total directly linked constructs	Number of direct linkages n-HVM	% of total directly linked constructs
1 (total)	420	100	420	100
2	222	53	168	40
3	144	34	90	21
4	109	26	51	12
5	75	18	33	8
6	53	13	24	6
7	42	10	18	4

To construct the f-HVM a cut-off level of f = 6 (Figure 2) presented a feasible balance between information and interpretation. This resulted in a HVM with 53 direct linkages between constructs, representing approximately 13% of the original linkages in the f-HVM (Table 1). Of the original 88 constructs 46 appear in the f-HVM (52%). Of the constructs that appeared in the f-HVM, 10 were classified as attributes, 21 as consequences, and 15 as personal values (Table 2). To construct a comparable n-HVM, a cut-off level of n = 4 was used (Figure 3). This cut-off level results in an n-HVM with 51 direct linkages between constructs, representing 12% of the total number of active linkages. In the n-HVM, 41 constructs (47%) appear of which 15 were classified as attributes, 20 as consequences, and 6 as personal values (Table 2). Using the same relative cut-off level (12%–13%), the reproduction of personal values in the f-HVM (60%) was much higher compared with the n-HVM (24%); whereas, in contrast, the number of attributes was slightly higher in the n-HVM (38%) compared with the f-HVM (25%). In both HVMs almost all the coded consequences were represented (Table 2).

Table 2. The total number of constructs classified as attributes, consequences and values and the number and percentage of constructs appearing in the *f*-HVM with cut-off level 6 and n-HVM with cut-off level 4. The selected cut-off levels keep the total number of appearing constructs closest to 50% for both algorithms.

Constructs	Total	f-HVM (cut-off level 6)		n-HVM (cut-off level 4)	
		n	%	n	%
Attributes	40	10	25%	15	38%
Consequences	23	21	91%	20	87%
Personal values	25	15	60%	6	24%
Constructs total	88	46	52%	41	47%

To further understand the effect of the used algorithm on the HVM, an n-HVM was constructed using the same absolute cut-off level (6) as the f-HVM (not presented). This n-HVM with cut-off level n = 6 showed only 24 direct linkages (6%), which is considerably less than the f-HVM with a cut-off level of 6. Also the integrity of the n-HVM is jeopardized at this cut-off level because several means-end chains are only partially reproduced: they either end or start at the level of consequences. From Table 2, it can be seen that construing an f-HVM with a cut-off of 4 (like the n-HVM in the previous analysis) would result in an impossible 109 direct linkages (26%).

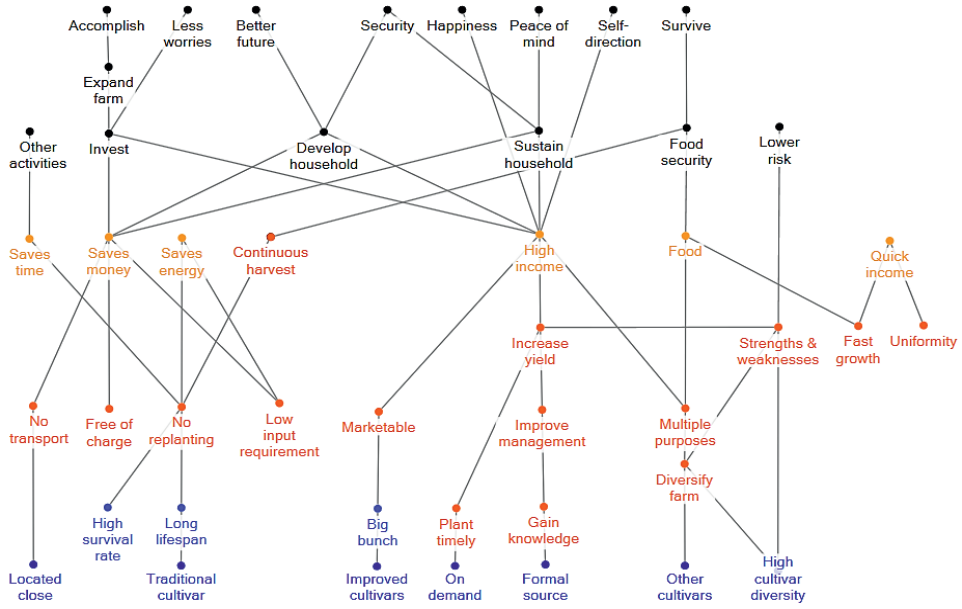


FIGURE 2. Frequency-based (f) hierarchical value map (f-HVM) based on the accumulated frequency of direct linkages between constructs made by the respondents. Attributes are presented in blue, consequences in orange, and values in black. n = 31; cutoff level: f = 6.

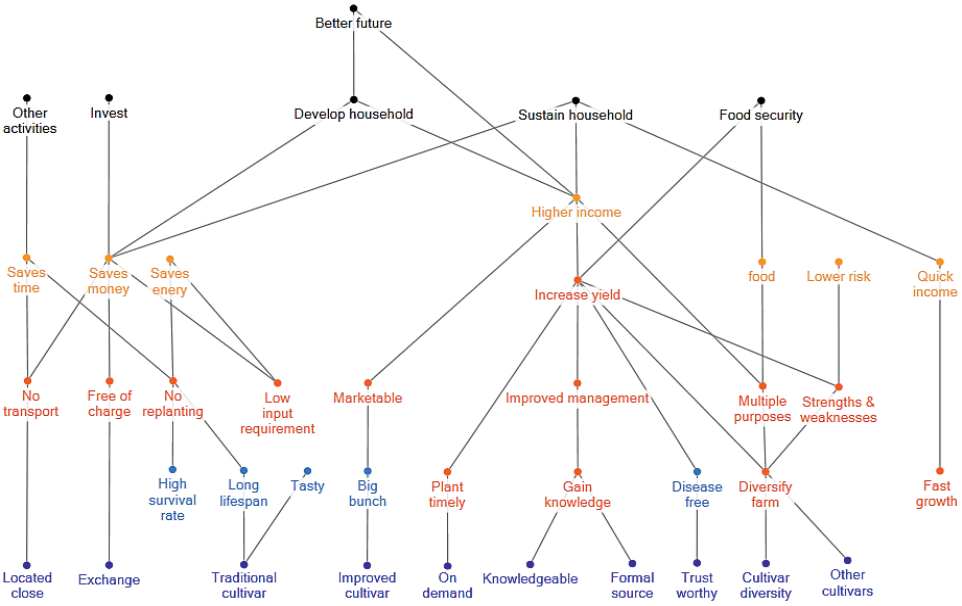


FIGURE 3. Number-of-respondents based (n) hierarchical value map (n-HVM) based on the number of respondents (n) making a linkage between constructs. Attributes are presented in blue, consequences in orange and values in black. n = 31; cutoff level: n = 4.

Applying the means-end chain analysis in a new research area

Means-end chain analysis takes different realities of respondents into consideration and therefore increasingly is used to explore farmers' tacit understanding of available resources relative to their goals and aspirations within their technological, ecological, and socio-economical context. Rather than forcing respondents into predetermined categories, the method enables respondents to define personally relevant constructs in their own words. Therefore the method is considered more suitable for research in cross-cultural settings compared with traditional survey approaches (Watkins, 2010). Moreover, the psychological theories on which means-end chain analysis is based have considerable overlap with theories underlying recent approaches to understand technological change in smallholder agriculture, such as the theory of affordance (Gibson & Carmichael, 1966; Glover et al., 2019). Whenever a method is applied in a new research area, it is advisable to review its underlying assumptions and evaluate if those still apply. Every research method and the underlying theories in which they are embedded are based upon a set of assumptions. Means-end chain analysis is a composition of several research techniques, like attribute elicitation and laddering interviews, which can be selected flexibly upon the researchers preference. This makes it challenging to find all the assumptions that underly both method and theory as they are scattered in literature and are specific to each study.

An example of an assumption underlying means-end chain theory is that associations are hierarchical and causal: attributes lead to consequences, and consequences lead to values (ACV hierarchy). Reynolds and Olson (2001) argue that: “one can even ask whether causality as a central guiding principle for organizing experience may be culture- specific, that is, mostly applicable to the Western civilizations.” The hierarchy assumption has been contested and was found to not hold in all cases (van Rekom & Wierenga, 2007). In our study, associations were not always made along the same hierarchy. “Expanding the farm” for example can be a value that is achieved by earning more money, but was for some farmers the means to generate more money or reach food security. However, it might be more appropriate to attribute this to the fact that farmers are producers than to culture-specific differences. In any type of production it is common to invest part of the profits made, to make more profits. While interviewing

producers it can therefore be expected that profit is named circular with investments, expanding and purchase of more production goods, rather than linear.

Another assumption underlying means-end chain analysis is that consumers cope with the tremendous diversity of choice by grouping products to reduce complexity (Fransella et al., 2004). A difference to take into consideration is that farmers are not regular consumers when it comes to buying farm inputs. They are customers investing in their own means of production. In that sense, they are experts and might take more aspects into consideration and make a more thorough decision. When applying means-end chain analysis, farmers, in contrast to regular consumers, might come up with more attributes and more elaborated ladders.

In our study, the average number of attributes elicited was 7 and the average number of ladders 16. This resulted in a total of 88 constructs and 420 links. While browsing through means-end chain literature, the number of elicited attributes and ladders seems to be relatively high and the percentage of linkages shown in the HVM low. Reynolds and Gutman (1988) state that: "It is typical that a cut-off of 4 relations with 50 respondents and 125 ladders will account for as many as two-thirds of all relations among elements." A HVM with a cut-off level of 4, among 31 respondents, showing less than a quarter of the total linkages thus seems to be relatively low. However, differences in the number of elicited attributes, ladders, and linkages and the share of them being presented also depends on the elicitation technique, laddering method, coding and condensation, cut-off level, and so forth. In addition, not all studies report the number of constructs and links elicited nor the percentage of them presented in the HVM. This makes it hard to make any comparative claims to confirm if means-end chain analysis with "experts" as consumers indeed leads to more constructs and more elaborate ladders.

CONCLUSION

The means-end chain analysis continues to be applied in a diverse field of scientific disciplines. Despite an extensive body of literature, there is no standardized or formalized way to apply the means-end chain method, and many methodological

variants exist. This paper has made new contributions to the methodological debate. It has not led to a more standardized method but rather to understanding the outcomes of different ways of application.

In this paper we have discussed four methodological issues that all seem to be related to underlying assumptions and the research area in which the mean-end chain method is applied. One of those assumptions is that people evaluate products and services based on dichotomous distinctions. There might be multiple underlying reasons why a person or a group of people do/do not perceive a certain dichotomy. This is a relevant consideration when means-end chain analysis is applied to compare groups of consumers. A second consideration is whether and how those dichotomous elicited constructs should be coded. We argue there is a difference between "coding" responses given in own words into common denominators and "condensing" responses by grouping subordinate constructs into a superordinate denominator. Condensing responses results in an increase and a loss of information at the same time. For studies aiming to understand how products or services are evaluated for example to improve product development, lower levels of condensation are more relevant, as more detailed information on the attributes is displayed. Studies focussed on marketing and advertisement or understanding why products are valued, might benefit of higher levels of condensation as it increases the probability attributes are linked to higher end constructs. A third unclarity addressed in this paper is which responses should be aggregated in the implication matrix. Frequency-of-responses-based aggregation favors individually dominant linkages relative to commonly shared linkages whereas number-of-respondents-based aggregation favors commonly shared linkages. Moreover is it not always clear what algorithm is used by available software to analyze laddering data. We therefore recommend researchers to explore how the used software program transform their ladders into chains presented in hierarchical value maps. Lastly, when means-end chain analysis is applied in a new research area it is relevant to evaluate the underlying assumptions. It is for example plausible that professional consumers come up with more personally relevant constructs and more elaborated ladders than regular consumers.

In conclusion, it does not seem possible to decide on "a best way" to apply means-end chain analysis. Different kinds of elicitation techniques, coding approaches, and aggregation algorithms can provide relevant information. The flexibility and differences rather allow for its application to understand a broad range of research questions. What is important is that researchers are aware of the effects of different ways of application, use this knowledge to make informed decisions in their research design, and report which decisions they have made and why.

CHAPTER

Seven

General Discussion and Conclusion

INTRODUCTION

The objective of this thesis is to apply and evaluate different research methods that can be used to understand smallholder farmers' seed-sourcing practices for vegetatively propagated crops. Farmers' seed-sourcing practices concern their choice of varieties, seed quantities, seed replacement, and seed source, i.e., their demand for seed. A better understanding of farmers' current seed-sourcing practices can improve the future design of seed-system interventions. Seed-system interventions are made to increase the availability of, improve access to, and expand the use of, improved seed among farmers; in other words, to increase the adoption, scaling, or diffusion of seed-related technologies and innovations. In the chapters of this thesis, four underlying objectives are addressed that contribute to the overarching objective:

- Objective 1: To describe the insights into farmers' seed-sourcing practices that are provided by different research methods (Chapters 2, 3, and 4)
- Objective 2: To explore how research methods can be improved and better adapted to understand farmers' seed-sourcing practices (Chapters 5 and 6)
- Objective 3: To explore how the research methods used create different presences and absences and complement a more holistic understanding of farmers' seed-sourcing practices (Chapter 7)
- Objective 4: To explore how the research methods used contribute not only to describing but also to shaping farmers' seed-sourcing practices (Chapter 7).

Insights on farmers' seed-sourcing practices provided by applying different research methods

The first objective of this thesis is to present the insights obtained with different research methods that contribute to understanding, explaining and predicting farmers' choices and decision making about seed. The various research methods applied in this

thesis each answer a different question, but they are all geared towards gaining insights into farmers' seed-sourcing practices. In Chapter 2, we show the results of a household survey administered among cassava farmers in Rwanda. These survey data provide the basis for developing farmer typologies that can be used to inform the tailored design of cassava seed business models. A seed tracing study is undertaken to explore how these different farmer typologies source their cassava seed. The results show that the majority of farmers of all typologies use mainly informal seed sources to access cassava stems. Nevertheless, many farmers of all typologies grow the improved varieties NASE14 because of its disease resistance and Macadamia because of its diverse end uses and early maturity. Where farmers access new (improved) varieties differs among typologies. Better-off typologies more often use formal seed sources to access them, whereas household typologies with less assets source them from fellow farmers. Because cassava can be multiplied while maintaining genetic characteristics, the majority of farmers proceed to multiply their seed themselves after a one-time acquisition of an improved variety from a formal seed source. Cassava's characteristics thus influence farmers' seed-sourcing practices, thereby complicating the development of commercial cassava seed businesses.

In Chapter 3, we show the results of an exploratory study using the four-square method and in-depth interviews. The four-square method is employed in this study to identify the banana varieties grown by farmers in Central Uganda, and why. Banana varieties have multiple purposes in the community because they have diverse end-uses and cultural meaning. These form important drivers for farmers to maintain a high diversity of (endemic) banana varieties. In the in-depth interviews, farmers explain that they have two main mechanisms to extend their banana farms' productive life. Because banana is a perennial crop farmers focus on increasing the lifespan of existing banana mats and plant new suckers when needed. Bananas' diverse end-uses and cultural meaning and the way in which banana mats are managed influence farmers' seed-sourcing practices in several ways: they determine what varieties farmers select, when a banana mat is uprooted and replaced, and hence the frequency and quantity of new suckers or other propagates needed.

In Chapter 4, we apply means-end chain analysis to understand how Ugandan farmers evaluate, and why they value, different sources for banana-planting material. The results show that farmers' main goals are to increase banana yield and income, thereby allowing them to sustain and develop the household for a better future. Although yield and income are the main goals, farmers have other goals such as reducing risk and saving time to spend on other activities. The goals that farmers pursue with their banana production generally overlap among different types of farmers, but the seed-sourcing practices that farmers perceive as enabling them to reach those goals differ. For example, all farmers aim to increase their available income. Some farmers explain that they prefer to source seed from informal seed sources that have local varieties available because their life-span is longer, allowing them to save money on the purchase of new suckers. Other farmers say that they prefer sources that have improved varieties available because they have bigger bunches, allowing them to achieve a higher market price.

In sum, these chapters provide several examples of how different aspects in the seed system - including biophysical aspects such as disease presence and the reproductive characteristics of crops, as well as social aspect such as cultural uses of crops and social norms guiding seed exchange - influence farmers' seed-sourcing practices in a variety of ways. It influences what varieties farmers grow, where farmers prefer to source them, when farmers decide to replace their seed, and hence how much seed is needed. Results also show that farmers' seed sourcing practices influence several aspects in the seed system - including biophysical aspects such as whether a disease will be controlled or if varieties disappear, and social ones such as the successfulness of commercial seed businesses and the roles a certain crops fulfils the community.

Improving and adapting research methods to understand farmers' seed-sourcing practices

The second objective of this thesis is to improve and better adapt research methods in order to better understand farmers' seed-sourcing practices. Chapters 5 and 6 are methodological contributions that examine assumptions underlying research methods and describe them in light of the context to which they are applied: smallholder farmers

in rural Africa sourcing vegetative seed. Chapters 5 and 6 show that methods from other research fields, such as economics and consumer behaviour studies, can be relevant for understanding farmers' seed-sourcing practices and provide useful insight from other angles, but that those method have to be adapted to the specific research context.

In Chapter 5, we show the results of a qualitative follow-up study on an experimental Vickery auction aiming to understand the value that farmers place on different types of sweetpotato vines. We find that several assumptions underlying experimental auctions may be violated when they are applied in this specific context. These violations result mainly from the characteristics of vegetative seed and of the smallholder farmers that use them. Vegetative seed is not a single unique indivisible object to be sold to one of a number of potential purchasers. Rather, it can be cloned, reproduced, and thereafter exchanged by farmers based on multiple economic mechanisms other than just market principles. The extent to which the violation of assumptions is problematic depends on the specific objective of the auction, as experimental auctions can be used for several types of measurements.

In Chapter 6, we evaluate means-end chain analysis. We use the same dataset as in Chapter 4 to discuss the underlying assumptions of the method. Three contributions to the general methodological debate around means-end chain analysis are made concerning attribute elicitation, response coding, and response aggregation. We conclude that different ways of data collection and analysis can be most appropriate or useful, depending on the specific research question that one aims to answer. Research concerning how products are evaluated can best apply number-of-respondents-based aggregation and low levels of condensation. Research concerning why products are valued can best apply frequency-of-responses-based aggregation and high levels of condensation. When means-end chain analysis is used to understand farmers' seed-sourcing practices, it is important to take into consideration that farmers are not just consumers, but rather consumers who invest in their own means of production. Therefore farmers, in contrast to regular consumers, might come up with more attributes and more elaborated ladders.

The findings of this thesis support the notion that it is not as much research methods in themselves that are problematic and need to be improved (Law, 2011). Rather, it is their application to inappropriate research questions and/or in an inappropriate context which is problematic. Improvements are thus made when researchers carefully consider what research methods are capable of answering their research questions, if they are capable of measuring what they opt to measure, and if underlying assumptions hold when applied in a specific research context.

As Objectives 1 and 2 are elaborately addressed in the separate chapters, I focus the further discussion mainly on Objectives 3 and 4, using the double social life of methods as an outline (Law et al., 2011). I start with the first social life of methods by illustrating, using my own empirical findings, how societal objectives drive approaches, theories and methods. This leads to the generation of different presences and absences. I reflect on their contribution to shaping farmers' decision making and seed systems. This reflection represents the second social life of methods.

METHODS ARE PART OF THE SOCIAL

Methods are of the social firstly because they are constituted by the social world of which they are part (Law et al., 2011). This thesis confirms that methods are developed, selected, and applied with a certain objective in mind that depends on societal interests. Regarding seed-system interventions, there is a common consensus that agricultural production in developing countries needs to increase and that using improved seed is one of the major ways to accomplish this. Increasing agricultural productivity contributes to several sustainable development goals set by the United Nations (United Nations General Assembly, 2015). Seed-system research is thus part of a larger overarching agenda of global development goals to which multiple actors – donors, governments, research institutes, NGOs, universities, and so forth – contribute. Those actors constitute the advocates of methods and their underlying theories and approaches.

Methods are driven by societal interests and objectives

To contribute to the objective of increased agricultural production in developing countries via seed, an approach is selected. Although the objective of increasing agricultural production via seed is in itself seldom questioned, the approaches to reach this objective differ and are debated (e.g., Scoones and Thompson, 2011; Ruzzante et al., 2021; McGuire, 2005). The research discussed in this thesis aligns with the market-driven approach (chapter 2 and 5), the integrated seed-systems approach (chapter 3), and the demand-driven approach (chapter 4). The aim in all approaches in fact is to better understand, explain, and predict farmers' demand for seed and could therefore be regarded as demand driven, but they have slightly different underlying goals. What the approaches furthermore have in common is that they involve the establishment and/or development of a formal seed sector.

Within each approach, certain theories fit and support it. The theories used in the chapters in this thesis are the diffusion of innovations theory (Chapter 2), the personal construct theory (Chapters 4, 5, and 6), and neoclassical economics (Chapter 5). Similar to approaches, theories overlap and can be linked. For example, in many studies that apply the diffusion of innovations theory, farmers, in line with a core assumption of neoclassical theory, are assumed to act rationally and maximize utility when selecting seed or deciding to adopt a technology. The selected theory further defines a) the relevant variables and thus which variables to include and exclude, and b) how these variables cohere. Because theory informs the choice of relevant variables, it guides researchers to select methods that are capable of a) collecting data on those variables deemed relevant and b) analysing them to find coherence. This inevitably has consequences for which variables and relations are captured and which are ignored. I will demonstrate this based on the findings of chapter 5.

Markets, neoclassical economic theory and experimental actions

The experimental auction study we used for our follow-up adopts a market-oriented approach. In brief, the underlying goal of market-driven approaches is to establish functional markets that will lead to optimal resource allocation (Beumer et al., 2022). Besides understanding demand, these approaches often involve 'demand creation' for

formally supplied seed. In the study used for our follow-up, the goal is to understand farmers' demand for different types of sweetpotato vines to prove the economic viability of establishing a commercial formal seed sector. The study made use of neoclassical economic theory which assumes that farmers make rational decisions with the objective of maximizing utility. Farmers' demand is assumed to correlate with preferences and prices. Further, farmers' demand is expected to vary in line with demographic and farming characteristics.

To collect data on those variables and correlations deemed relevant by neoclassical economic theory, experimental (Vickery) auctions are used. Farmers are requested to express their valuation of different sweetpotato vines in monetary terms via bids. Those bids are subsequently plotted in a demand curve to find correlations between preferences and prices. To understand which and how demographic and farming characteristics influence bids, surveys are conducted pre and post the bidding rounds. An econometric analysis is applied to explore which of the demographic and farming characteristics have an influence on bids, and how. The study finds that farmers are willing to pay premium prices for quality vines of orange-fleshed sweetpotato varieties upon receiving information on their benefits. Furthermore are several household and farming characteristics, such as gender of the household and access to marshland, identified as drivers behind farmers' demand for sweetpotato vines (Okumu et al., 2021).

Demand, personal construct theory and qualitative case studies

In demand-driven approaches, the goal is to understand farmers' demand for seed so that formal seed supply can be tailored to that demand (Almekinders et al., 2021), rather than demand creation. Chapter 5 provides a qualitative account of the same auction-event, which leads to additional and other insights. Instead of using neoclassical economic theory, we based our study on psychological theories such as the personal construct theory. The personal construct theory builds on the assumption that everyone constructs a mental representation for making sense of, and acting upon, the world that they experience (Brunswik, 1943; Kelly, 1955). This personal mental representation consists of a web of functional associations and informal hypotheses

that predict personally relevant consequences from observable cues (Neisser, 1976; Peirce, 1878; Tolman & Brunswik, 1935).

Because the personal construct theory assumes that people perceive personally relevant cues that they can put to use, we apply a repertory grid analysis, as it can identify those cues. This methods allows farmers themselves to select and verbalize personally relevant attributes for the evaluation of different seeds and sources. Via observations in-depth interviews is further explored how farmers interpreted the event, what their strategies were during the experiment, and how social norms and cultural values play a role in farmers' acquisition of sweetpotato vines. We find that farmers, in valuing the sweetpotato vines, may use product characteristics other than those controlled for in the experiment. Furthermore we find indications that farmers make different decisions in real-life than in the experimental context because in real-life farmers decisions depend on other economic mechanisms than only market principles. We also identify that during the experiment some farmers have objectives other than maximizing the pre-defined utility function. This is the result of various ways in which farmers understood the experiment.

These two accounts of the same experiment demonstrate that depending on the used theory and the way they inform methods, data is abstracted from this event in a different way. Therewith different aspects of farmers' sourcing practices are captured whereas others are ignored. In the next section I will focus on the aspects of farmers' demand that are captured and ignored by the applied research methods.

The different aspects of farmers' seed-sourcing practices revealed by research methods

Using chapter 5 of this thesis as an example I have demonstrated that versions of the social are embedded in our research methods used in seed-system research. This starts with the selection of an approach and associated theory to address an objective. Theory defines which variables are relevant and how they cohere. A data collection method is selected that can capture these variables deemed relevant, and a data analysis method is selected to find coherence. Therefore, methods reveal different aspects of farmers' seed-sourcing practices, while leaving others aspects in the dark.

Surveys collect data on a standardized set of variables from a relatively large number of households. In Chapter 2, such data are used to cluster cassava farmers into typologies that share similar characteristics forming a distinct type. It is further described how these types source their cassava seed compared with other types. Because of this large dataset, statistics can be used to identify whether a certain type of farmer is above or below a mean, performs better or worse, or is more or less likely to use improved seed or formal seed sources. Therefore, the method can identify *diverse demands* of different types of cassava farmers whose demand at first might appear to be homogenous. The large sample sizes mean that survey data can reveal important correlations between variables and behaviour. The experimental auction used as a follow-up similarly has a large sample size. This ensures that bids can be correlated to characteristics and show statistically how they relate to preferences and willingness-to-pay.

Surveys and experimental auctions collect data in a standardized way on the variables on which they are supposed to collect data. In that sense, they are not very sensitive to novelties and the identification of other variables that could be relevant. Although they find relevant correlations between specifically selected variables, surveys do not necessarily explain the underlying reasons for the correlations. For example, the Chapter 2 results show that farmers who can be regarded as more entrepreneurial make more use of formal seed sources, but they do not explain the key drivers for those farmers to use them. Such explanations can only be sought in the literature or through additional research. Furthermore, survey data can reveal a correlation, but not always causality. Wealthier households may make different decisions regarding varieties and sources, but those different decisions may also explain why some farmers become wealthier. Therefore, surveys and auctions may overlook aspects of demand, and key drivers behind demand, that originate from specific world-views. I further refer to this as *subjective demand*.

In contrast to correlating many pre-defined variables, focus group discussions, interviews, and means-end chain analysis have a more exploratory nature and leave room for farmers to indicate the variables that are personally relevant to them. In many

adoption studies, the assumption is that farmers make decisions about the adoption of a technology with the objective of maximizing utility (generally defined as yield and income). In Chapter 3, we demonstrate that banana farmers in Central Uganda have other drivers behind their decisions that are not always on researchers' radar. Farmers might select seed of a specific variety even though it is low yielding, because the variety fulfils a specific cultural meaning or use. Means-end chain analysis transforms qualitative data into quantitative data to generate an overview of the way in which certain groups of farmers evaluate seeds or seed sources, and why they value them. Such small-N exploratory case studies therefore identify subjective demand and aim to find the key drivers behind farmers' seed-sourcing practices from their perspectives.

Results obtained with exploratory case studies can also be differentiated for groups. The relevant groups for comparison are usually determined by researchers. Even though the results in Chapters 3 and 4 are differentiated by groups, such differences give only an indication of a possible trend and lack the statistical power to be representative. Correlations between variables cannot easily be statistically demonstrated, or whether the defined groups are significantly below or above a mean. Thus, small-N case studies employing focus group discussions, in-depth interviews, and means-end chain analysis can give insight into subjective demand and indications about diverse demands, but with a low representativeness. Surveys can find correlations, but case studies can help to identify relevant variables, understand underlying reasons for correlations, and find causality. Combining methods that capture diverse demand and subjective demand can thus provide a more holistic understanding of farmers' demand for seed.

In addition to being diverse and subjective, demand can be expressed at different levels of abstraction (Leeuwis, 2022). In some cases, it might be easier for users to articulate a higher-level need, such as food security, than a specific demand that fulfils that need, such as quality seed, or vice versa. Means-end chain analysis is the only method used that gives insights structurally into those different *layers of demand*. Thanks to the laddering technique used in interviews, relevant demands and needs at different levels of abstraction are captured and linked hierarchically. Concrete attributes (such as a

local variety) are linked via different intermediate constructs to higher-level abstract needs and goals (such as sustaining the household).

All methods study farmers' demand for seed at a specific point in time and therefore might ignore *emerging and evolving demand*. Demand for seed can be implicit, for example because farmers are unaware of the continuously evolving breeding possibilities. Once farmers obtain information about those possibilities, a demand might emerge. Farmers' seed demand can also evolve as farmers gain user experience, for example when it turns out that a certain variety requires different management practices. Experimental auctions are theoretically the most promising method for capturing emerging and evolving demand. They are often applied with the aim of predicting future demand for a good. Another objective of the experimental auction is to understand farmers' demand under different conditions. In the study used for follow-up in chapter 5 changes in demand are observed after information is provided on the benefits of the sweetpotato vines and their sources. Despite this theoretical potential, the characteristics of vegetative seed complicate such predictions. If auctions were adapted to be more compatible with the context, they could make valuable contributions to capturing emerging and evolving demand.

Finally, demand can have substantive, economic, and political connotations (Leeuwis, 2022). In all methods, the assumption is that farmers' demand for seed de facto refers to a substantive demand. The question that the methods aim to answer is what, where, how much, and why seed is obtained by farmers. For example, via experimental auctions, researchers aim to estimate a price at which farmers might be willing to buy a certain seed – an economic demand. Whether a farmer would actually use the seed or source selected in the experimental setting remains unknown, as in many cases the experimental context is void of alternative choices that do exist in real life. Even when a certain type of seed or source is preferred during the experiment, farmers might go for a different option when other household needs are prioritized. The possibility of exerting an economic demand does not guarantee a substantive demand, i.e., in some cases a farmer might be able to make a purchase but not willing, and vice versa. Similarly, means-end chain analysis compares perspectives on fairly similar seeds or

sources selected by researchers on the assumption that there is a demand for that product or service. Choices between different seeds and sources are studied, but not between seeds and other household needs.

In sum, methods shed light on different aspects of farmers' seed-sourcing practices, and combining them can result in a more holistic image. Nevertheless, there might always be aspects that slip through the net and are ignored. None of the applied methods seems specifically capable of capturing how farmers' demand for seed emerges and evolves – at least not when applied once at a single point in time. Furthermore, they do not capture substantive demand in real-life conditions when decision making involves many other household needs. Making the differences between methods, as well as their limitations, visible is a first step towards the complex understanding of farmers' demand (Pircher and Almekinders, 2020).

THE PERORMATIVE NATURE OF METHODS

Seed systems are complex and concern the interaction of multiple aspects in the biophysical and the social sphere. The decisions that actors within seed systems make depend on those diverse and interacting aspects, and simultaneously shape them. Because of the complexity of seed systems, the selected assessment methods often result in a partial, skewed, or blurred understanding of farmers' seed-sourcing practices and the underlying motivations for their decisions (Almekinders et al., 2019b). In the previous section of this discussion, I demonstrate that each research method can capture only certain aspects of farmers' seed-sourcing practices. Informed by theory, they focus on different variables and find different relations between those variables, thereby generating different presences and absences. Presence refers to that which is made present via statements, representations, objects, and processes. Absence refers to parts of reality not made present but which are necessary to define presence (Law, 2004). These absences can be manifested or remain hidden or invisible. In the following section, I explore how methods are performative by making things present, while ignoring what remains absent.

Methods are performative by making presences and ignoring absences

As indicated earlier, the global objective defined by the United Nations is sustainable development, which requires an increase in agricultural production; and there is a general consensus that using *improved seed* can make a major contribution to this objective. Several seed-system approaches exist, such as the market-driven approach, the integrated seed-systems approach, and the demand-oriented approach. What those approaches have in common is that they involve an envisioned role for a *formal seed sector* to provide improved seed and that farmers should *adopt* them, albeit via different *mechanisms* such as the development of markets or integrated seed systems. I shall explain how the studies described in this thesis contribute to performing these narratives. This means that research methods are not just tools to describe reality objectively, but also actively contribute to enacting the reality that they describe.

The making of seed quality: improved seed equals quality seed?

Seeds have different qualities. In many academic circles and in the formal seed sector, improved seed generally means seed of high quality. Seed quality is defined by a set of measurable characteristics on which it can be rated and scored. According to formal sector standards quality seed is generally high yielding, uniform, and variety pure, has a high germination rate and vigour, and is free of pathogens. Via our research, the relation between those characteristics and quality is made and remade. Formal sector standards focus on quantification of seed quality. Via standardized protocols seed lots' purity, germination rate, and infection rate, etc. are tested. The results of those tests are described on labels and seed certificates and used to sort seed lots into different classes.

The formally defined characteristics that make up seed quality might seem universally desirable, but this is not always the case. We find indications among Rwandan cassava farmers who, when asked if they "*have access to enough quality cassava seed*", are likely to interpret quality in a different way. In the same study, we report that researchers use the starch level of cassava roots as a measurement standard for the quality of a variety. Nevertheless, farmers widely adopt the new cassava variety, Macadamia, whose starch level is below this threshold. In the study among banana farmers in Uganda, we find that farmers perceive local varieties as quality because of

their long lifespans. Moreover, some farmers prefer a mixture of varieties to spread risk and fulfil several end-uses. Focussing on by the formal sector defined quality characteristics ignores the local meanings of seed that compose quality according to farmers' perceptions. Our research findings are used to inform breeders and policymakers. Thus, what is defined as quality seed shapes what seeds are made available by the formal sector now and in the future.

The making and remaking of formal and informal seed systems

We could argue that informal seed systems roughly did not 'exist' before the 1990s. They were made present by, for example, Linnemann and de Bruijn (1987), Cromwell (1990), and Almekinders et al. (1994). Before that, the informal seed system was an absence, and seed system de facto referred to what we now define as the formal seed system (Douglas, 1980). For the informal seed system to survive and be turned into fact, it needs to be referred to in a next generation of scientific research and papers (Latour, 1987). For example, a result obtained with survey research in Chapter 2 is that "*90% of the Rwandan farmers source their cassava seed via the informal seed system*". This statement amplifies the existence of a formal and an informal seed system as previously defined by research. Similarly, our means-end chain analysis re-enacts that reality. An insight obtained with means-end chain analysis is that: "*The majority of farmers prefer informal seed sources because they have traditional varieties available*". Farmers' literal responses when evaluating different seed sources are that tissue-culture laboratories or government institutes are 'not farmers', who 'specialize in seed multiplication', or who are 'professional seed producers'. To allow aggregation of such responses, we code these as formal seed sources. These characteristics initially named by farmers match what we in the scientific community refer to as a formal seed source. Researchers code the responses with their knowledge of logic ordering and categorization within seed-systems research.

This binary divide between formal and informal seed systems is thus made and remade via scientific methods, even if methods are used that allow farmers themselves to indicate the relevant attributes of seed sources. The inner workings of these relatively recent described informal seed systems are mainly hidden and invisible, especially for

outsiders. It used to be – and for a large part still is – unknown where, what, why, how frequently, and in what quantities smallholder farmers in rural Africa obtain their seeds. This existing but complex, multi-layered, largely autonomous, and polycentric seed-provision system is labelled informal, whereas the formal system is simple, linear, hierarchical, and centrally organized.

As previously described, research methods reveal different aspects of farmers' seed-sourcing practices. In Chapters 3 and 4, via case studies, the relationship between farmers, their culture, and agriculture is described. In Chapter 5, in a qualitative follow-up to an experimental auction, we emphasize the underlying social relationships that influence farmers' seed-sourcing practices. From this same experimental auction, data are abstracted for econometric analysis and the generation of demand curves. This largely ignores social relations and instead focuses on quantifiable relationships between variables. Surveys are similarly constructed from a worldview of quantifiable relationships and construct a world of quantifiable relationships. They make visible and quantify seed flows, seed volumes, networks, transactions, and so on.

Via research new aspects of the seed systems are revealed and described in statements about them which remakes them in slightly different ways. If methods such as surveys gain hegemony on our research agenda, this means that the localized meanings or enactments of seeds and their exchange are repressed. Multiplicity makes way for singularity and 'finding ways to understand the complexity of seed systems' becomes 'create understandable seed systems'.

Promoting individual instead of collective approaches

Agricultural production can increase through the development and diffusion of improved seeds. In practice, many studies regarding the adoption of seed related innovations focus on the innovation-decision process rather than diffusion. Therefore, the unit of analysis shifts from community dynamics to individual decision behaviour. The same statements – "*90% of the Rwandan farmers source their cassava seed via the informal seed system*" and "*The majority of farmers prefer informal seed sources because they have traditional varieties available*" – amplify that farmers are decision makers who have preferences for certain seeds and sources. Research methods that aim

to understand, explain, or predict how farmers make these decisions include a theoretical representation of humans, or 'model of man', which embeds assumptions on what a human being is and does. These models of man differ among disciplines such as psychology, neoclassical economics, and adoption theory.

The means-end chain analysis used in Chapters 4 and 6 is embedded mainly in psychological theory, which assumes that people perceive the world in terms of personally relevant uses and that their decision making depends on those perceptions (Von Uexküll, 1920; Brunswik, 1943 Kelly, 1955; Gibson and Carmichael, 1966). The theory of affordances (Glover et al., 2019) and the theory of jobs to be done (Christensen, 2016) take a similar pragmatic stand. The model of human behaviour used in neoclassical economics on which Vickrey auctions are based is often referred to as *Homo economicus*: economic man. Homo economicus is assumed always to act rationally with the aim of maximizing utility. Furthermore, (s)he is self-interested, has consistent preferences, and makes rational decisions based on available information. The diffusion of innovation theory assumes that societies are composed of a range of adopter categories: innovators, early adopters, early majority, late majority, and laggards.

The question then is whether these models are just theories that can be used objectively to study how humans make their decisions, or whether they actually contribute to realizing the behaviour that they depict and shape decision making. Describing human behaviour using similar scientific laws as in the natural sciences implies a search for necessary and sufficient conditions of observable behaviour. Large-N household surveys can identify the *characteristics* of people who make decisions 'as they should' according to a specific behavioural theory. For example, in neoclassical economics, this is the characteristics of people who act rationally and are utility maximizing. According to adoption theory, those people fall under the innovator adopter category. In a similar fashion, auctions can identify the right *conditions* under which participants display this optimal behaviour.

Consequently, those laboratory conditions in which desired decision-making behaviour is displayed should be mimicked in the real world. For example, for farmers

to make 'the right decision', they need observable and calculable information on seed quality and sources, such as germination rates, yield potential, and prices. Thus, the quantification of seed quality and seed systems is a requirement for rational, calculative, and maximizing behaviour. This further suggests that irrational or sub-optimal behaviour can be 'cured' and that optimal behaviour can be learned when people are set in the right environment (Berndt, 2015). Instead of reforming behavioural theory to match reality, the right conditions are identified in which the desired theory works (Guala, 2007). The performativity of social science implies that the shift in focus towards individual behaviour has consequences, as 'understanding rural communities' becomes 'creating communities as we understand them'. This would mean that scientific methods are tools not merely for understanding, explaining, or predicting farmers' choices, but simultaneously for shaping, influencing, and controlling choice (Streeck, 2010).

The focus on the individual means that interventions and agricultural extension services are also geared towards changing the individual, instead of changing products (e.g. seeds), economies (e.g. seed exchange mechanisms), or policies (e.g. seed laws) to suit communities. For example, certain interventions and extension services demonstrate to farmers, and give them the means to calculate, that the use of clean seed is beneficial. Nevertheless, in the case of vegetatively propagated crops the use of clean seed does not always have a clear and direct individual benefit. Farm-saved seed can perform as well as e.g. certified (clean) seed. Use of clean seed has however a clear advantage on a community level. Assuring a continuous and sufficient influx of clean seed in the seed system can prevent outbreaks of pests and diseases as they are accelerated by farmer-to-farmer seed exchange. Gearing interventions towards the value for the community of the overall health of the seed system might therefore be more beneficial than focussing on the individual gains for farmers by using clean seed.

Remaking farmers' social relations and the relation between farmers and their seeds

It is often assumed that market mechanisms are critical for the development of a formal seed sector and the adoption of improved seed. However, other non-market economic mechanisms might be equally important (Beumer et al., 2022). For example, the results

in Chapters 2 and 3 suggest that government interventions, whereby large-scale farmers are requested to multiply improved seed and share this with fellow community members, are rather successful diffusion mechanisms. Such mechanisms can be regarded as reciprocal economies, which Beumer et al. (2022) define as the exchange of gifts not based on the market value of the good – an exchange not driven by the profit motive. Giving and taking is instead based on the relative status of a member in the community and defines obligations to give and reciprocate in a certain way.

Nevertheless, such government initiatives based on reciprocal economies often have a deeper underlying objective to replace these 'economically unsustainable' exchange mechanisms with more sustainable forms of market exchange. It is assumed that, once farmers become familiar with the benefits of improved seeds, they will start purchasing them (Indimuli, 2013). This idea that familiarization with improved seed will create future market demand seems unsuccessful in Uganda, as many of the banana nurseries established through interventions were basically non-operational because of a lack of demand (Kilwinger et al., 2017). In general, the idea that non-market economies will naturally be replaced by the more efficient market economy can be contested. Many interventions have contributed to making markets (MacKenzie, Muniesa and Siu, 2007), often requiring a change in social relations and in the relations between humans and their environment. Economic systems, like seed systems, both give rise to, and are shaped by, social relations.

Current social relations among smallholder-farmers in East Africa result largely in subsistence economies where vegetatively propagated planting material is governed as commons (Beumer, 2021). New social relations and new relations between farmers and between farmers and their crops are required to turn seeds into commodities circulating in market economies. Commercialization and market development might lead to higher agricultural productivity, increase returns on investments, optimize resource allocation, and farmers might make rational and utility-maximizing decisions, but these statements thrive in their own world. When statements travel through space and time, they get into trouble, as they need to be accompanied by their own world. In this discussion, I have demonstrated that our research methods contribute to realizing

those required worlds. They make seed quality observable and calculable, track and quantify exchanges and seed flows, identify the characteristics of those who make decisions 'as they should', and ascertain farmers' value for seed expressed in prices. In other words, the real is realized within a network of practices that enact and perform it (Law and Mol, 2001), and an environment starts to exist in which the statements survive (Callon, 2007).

It is not uncommon in the commodification process that the relations between humans and their crops have to be remade in another way (Holm, 2007; Callon, 2007). Upscaling an innovation means that current practices have to be downscaled in favour of new alternatives (Wigboldus et al., 2016). When applying multiple methods and aiming to get a more holistic image of seed systems, we are better aware of the realities that might possibly be silenced, and can consider whether this is desirable. When research is focused only on market-driven approaches, we are looking for the characteristics and conditions that enable high adoption percentages and a fast turnover of improved seed supplied by the formal seed sector. What we might ignore when finding these conditions are the relations between culture and agriculture, such as the diverse cultural end-uses that are key drivers behind the preservation of banana varieties in Central Uganda. As a result, disentanglement of those current relation between culture and agriculture might be inevitable.

CONCLUSIONS

Which way to go with seed systems?

In this discussion, I use examples from the chapters of this thesis to demonstrate that, in seed-system research, methods are not purely technical tools to describe or report reality. They have a performative nature by making certain aspects of farmers' seed-sourcing practices present, while ignoring others. Furthermore, I show how the enactments of realities produced by research methods, such as quality seed and informal seed systems, do not automatically stay in place but have to be made and remade. This means that they can be remade in other ways as well (Law, 2004; Callon,

2020). The question then becomes, what are the realities that we want to enact and recreate? And then, and as part of this, it is about the kinds of people that we want to be and how we should live (Addelson, 1994). This is a big thing for us to decide for ourselves, but an even bigger thing for philanthropists, scientists, and development organizations to decide for rural farming communities.

Should we continue with the commodification of agriculture in developing countries and enacting homo economicus, the rational and profit-maximizing human? Or should we try to strengthen seed systems that are still governed as commons, enacting humans as individuals embedded in social relations, morality, and the environment? Those are questions that we need to make transparent and think about, together with those whose lives are eventually affected. What appears at least is that capitalism, marketization, and commodification are not destiny. Seed systems are diverse, the seeds circulating within them are diverse, and this is the result of farmers' diverse cultural practices. This means that diverse research methods are required in order to understand (and enact) farmers' seed-sourcing practices.

The performativity thesis stimulates us to focus on what works instead of just considering what is true or false (Callon, 2007). This opens up the possibility of multiplicity, as there is no pre-given right or true path to follow: solutions can be diverse. Including different research methods from several disciplines, such as the root, tuber, and banana seed toolbox, is a first step towards a more holistic understanding of farmers' seed sourcing practices that can serve those diverse solutions. Understanding what those methods actually do is a second step. Recognizing performativity means that, in science in general, it is not the environment that decides and selects which statements will survive; it is the statements themselves that define the environments required for their survival (Callon, 2007). In a similar fashion, this thesis demonstrates that it is not just that improved seeds are adapted to suit farmers' seed-sourcing practices, but also that improved seeds define what farmers' seed-sourcing practices should look like.

REFERENCES

Adam RI, Badstue L and Sindi K (2018) The dynamics of smallholder farmers' acquisition and distribution of Sweetpotato vines in the lake Victoria zone region, Tanzania. *Food Security* 10(2): 339–350.

Addelson K (1994) *Moral Passages: Towards a Collectivist Moral Theory*. New York and London: Routledge.

Adekambi SA, Okello JJ, Rajendran S, et al. (2020) Effect of varietal attributes on the adoption of an orange-fleshed sweetpotato variety in Upper East and Northern Ghana. *Outlook on Agriculture* 49(4): 311-320.

AGRA (2022) Partnership for Inclusive Agricultural Transformation in Africa (PIATA). Available at: https://agra.org/piata/. (Accessed 14 March 2022).

Akerlof GA (1970) The market for "lemons": Quality uncertainty and the market mechanism. *The Quarterly Journal of Economics* 84(3): 488-500.

Alderson W (1957) *Marketing behavior and executive action; a functionalist approach to marketing theory.* Homewood: R.D. Irwin.

Alicai T, Omongo CA, Maruthi MN, et al. (2007) Re-emergence of cassava brown streak disease in Uganda. *Plant Disease* 91: 24–29.

Alliance for Food Sovereignty in Africa (2021) Open letter: The Green Revolution in Africa has unequivocally failed. African Arguments, 15 September 2021. Available at: https://africanarguments.org/2021/09/open-letter-the-green-revolution-in-africa-has-unequivocally-failed/ (accessed 16 January 2022).

Almekinders CJM and Elings A (2001) Collaboration of farmers and breeders: Participatory crop improvement in perspective. *Euphytica* 122(3): 425-438.

Almekinders CJM, and NP Louwaars (2002) The Importance of the Farmers' Seed Systems in a Functional National Seed Sector. *Journal of New Seeds* 4(1–2): 15–33.

Almekinders CJM, Beumer K, Hauser M, et al. (2019b) Understanding the relations between farmers' seed demand and research methods: the challenge to do better. *Outlook on Agriculture* 48(1): 16–21.

Almekinders CJM, Louwaars NP and De Bruijn GH (1994) Local seed systems and their importance for an improved seed supply in developing countries. *Euphytica* 78(3): 207–216.

Almekinders CJM, Mausch K and Donovan J (2021) Editorial introduction: Design issues and practical questions for demand-oriented seed systems. *Outlook on Agriculture* 50(4): 353-355.

Almekinders CJM, Ronner E and van Heerwaarden J (2020) Tracing legume seed diffusion beyond demonstration trials: An exploration of sharing mechanisms. *Outlook on Agriculture* 49(1): 29–38.

Almekinders CJM, Walsh S, Jacobsen KS, et al. (2019a) Why interventions in the seed systems of roots, tubers and bananas crops do not reach their full potential. *Food Security* 11(1): 23–42.

Alvarez S, Timler CJ, Michalscheck M, et al. (2018) Capturing farm diversity with hypothesis-based typologies: An innovative methodological framework for farming system typology development. *PLoS One* 13(5): e0194757.

Anastasiadis F and van Dam YK (2014) Consumer driven supply chains: The case of Dutch organic tomato. *Agricultural Engineering International* (special issue 2014): 11–20.

Andersson JA and Sumberg J (2017) Knowledge politics in development-oriented agronomy. In Sumberg J (eds) *Agronomy for development: The politics of knowledge in agricultural research.* London: Routledge, pp. 1-13

Andrade-Piedra JL, Almekinders CJM, McEwan MA, et al. (2020). *User guide to the toolbox for working with root, tuber and banana seed systems.* CGIAR Research Program on Roots, Tubers and Bananas (RTB), RTB User guide, 1. Lima: RTB,

Andrade-Piedra JL, Bentley JW, Almekinders CJM, et al. (2016) *Case Studies of Roots, Tubers and Bananas Seed Systems.* CGIAR Research Program on Roots, Tubers and Bananas (RTB), Working Paper No. 2016-3. Lima: RTB.

Arora S and Glover D (2017) *Power in practice: insights from technography and actor-network theory for agricultural sustainability*. STEPS Working Paper 100. Brighton: STEPS Centre.

Ashby J and Polar V (2019) The implications of gender relations for modern approaches to crop improvement and plant breeding. In: Sachs CE (eds) *Gender, Agriculture and Agrarian Transformations: Changing Relations in Africa, Latin America and Asia.* London: Routledge, pp. 11–34.

Aurifeille JM and Valette-Florence P (1995) Determination of the dominant means-end chains: A constrained clustering approach. *International Journal of Research in Marketing* 12(3): 267–278.

Bagamba F, Burger K and Tushemereirwe WK (2010) Banana (MUSA SPP.) production characteristics and performance in Uganda. *Acta Horticulturae* 879: 187–198.

Bagozzi RP and Dabholkar PA (1994) Consumer recycling goals and their effect on decisions to recycle: A means-end chain analysis. *Psychology & Marketing* 11(4): 313–340.

Bagozzi RP and Dabholkar PA (2000) Discursive psychology: An alternative conceptual foundation to means–end chain theory. *Psychology & Marketing* 17(7): 535–586.

Barker I, Jones R and Klauser D (2021) Smallholder seed systems for sustainability. In: Klauser D and Robinson M (eds) *The Sustainable Intensification of Smallholder Farming Systems.* Cambridge: Burleigh Dodds Science Publishing, pp. 1–18.

Barrena R, Garcia T and Sanchez M (2015) Analysis of personal and cultural values as key determinants of novel food acceptance. Application to an ethnic product. *Appetite* 87: 205–214.

Barrett CB, Bezuneh M, Clay DC, et al. (2001) *Heterogeneous Contraints, Incentives, and Income Diversification Strategies in Rural Africa*. Working Paper, Report no. 642-2016-43959, New York: Department of Applied Economics and Management, Cornell University.

Bartle B and Maredia MK (2019) *'The Effect of Quality Signaling and Trust on Willingness to Pay for Potato Planting Material: A Research Study in Kenya'.* Agricultural & Applied Economics Association Annual Meeting. Atlanta, 21–23 July 2019.

Bech-Larsen T (2001) Model-based development and testing of advertising messages: A comparative study of two campaign proposals based on the MECCAS model and a conventional approach. *International Journal of Advertising* 20(4): 499–519.

Bech-Larsen T and Nielsen NA (1999) A comparison of five elicitation techniques for elicitation of attributes of low involvement products. *Journal of Economic Psychology* 20(3): 315–341.

Bellon MR (1996) The Dynamics of Crop Infraspecific Diversity: A Conceptual Framework at the Farmer Level. *Economic Botany* 50(1): 26–39.

Bentley JW, Andrade-Piedra JL, Demo P, et al. (2018) Understanding root, tuber, and banana seed systems and coordination breakdown: A multi-stakeholder framework. *Journal of Crop Improvement* 32(5): 599–621.

Bentley JW, Nitturkar H, Obisesan D, et al. (2020) Is there a space for medium-sized cassava seed growers in Nigeria? *Journal of Crop Improvement* 34(1): 16.

Berndt C (2015) Behavioural economics, experimentalism and the marketization of development. *Economy and Society* 44(4): 567-591.

Beumer K, Maat H and Glover D (2022) It's not the market, stupid: On the importance of non-market economies in sustainability transitions. *Environmental Innovation and Societal Transitions* 42: 429-441.

Beumer K, Stemerding D and Swart JA (2021) Innovation and the commons: lessons from the governance of genetic resources in potato breeding. *Agriculture and Human Values* 38(2): 525-539.

Blomme G, Jacobsen K, Ocimati W, et al. (2014) Fine-tuning banana Xanthomonas wilt control options over the past decade in East and Central Africa. *European Journal of Plant Pathology* 139(2): 271–287.

Boadu P, Aidoo R, Ohene-Yankyera K, et al. (2019) A latent class modelling approach to evaluating farmers' preferences for pona seed yam certification systems and their willingness to pay in Ghana. *International Journal of Agricultural Extension and Rural Development Studies* 6(1): 1–25

Bollier D (2014) *Think like a commoner: A short introduction to the life of the commons.* Gabriola Island: New Society Publishers.

Bourne H and Jenkins M (2005) Eliciting managers' personal values: An adaptation of the laddering interview method. *Organizational Research Methods* 8(4): 410–428.

Breidert C, Hahsler M and Reutterer T (2006) A review of methods for measuring willingness-to-pay. *Innovative marketing* 2(4): 8-32.

Briesch RA, Krishnamurthi L, Mazumdar T, et al. (1997) A comparative analysis of reference price models. *Journal of Consumer Research* 24(2): 202-214.

Brown S (2002) Reading Wroe: On the biopoetics of Alderson's functionalism. *Marketing Theory* 2(3): 243–271.

Brunswik E (1943) Organismic achievement and environmental probability. *Psychological Review* 50(3): 255–272.

Brush SB (1995) In situ conservation of landraces in centers of crop diversity. *Crop science* 35(2): 346-354.

Callon M (2007) What does it mean to say that economics is performative. In MacKenzie D, Muniesa F and Siu L (eds) *Do Economists Make Markets? On the Performativity of Economics.* Princeton: Princeton University Press, pp. 311-357

Campos H (2021) The quest for innovation: Addressing user needs and value creation. In: Campos H (eds) *The Innovation Revolution in Agriculture: A Roadmap to Value Creation.* Cham: Springer, pp. 1–29.

Canavari M, Drichoutis AC, Lusk JL and Nayga Jr RM (2019) How to run an experimental auction: A review of recent advances. *European Review of Agricultural Economics* 46(5): 862-922.

Chaudhary P, Gauchan D, Rana RB, et al. (2004) Potential Loss of Rice Landraces from A Terai Community in Nepal: A Case Study from Kachorwa, Bara. *Plant Genetic Resources Newsletter* 137: 1–18.

Christensen CM, Hall T, Dillon K et al. (2016) Know your customers' jobs to be done. *Harvard Business Review* 94(9): 54-62.

CIP (2021) Crops to End Hunger: Accelerating Seed Delivery through Sustainable Seed Systems. CIP News, 26 July 2021. Available at: https://cipotato.org/blog/crops-end-hunger-accelerating-seed-delivery/ (Accessed 14 March 2022).

Coomes OT, McGuire SJ, Garine E, et al. (2015) Farmer seed networks make a limited contribution to agriculture? Four common misconceptions. *Food Policy* 56: 41–50.

Corrigan JR, Depositario DPT, Nayga Jr, RM, et al. (2009) Comparing open-ended choice experiments and experimental auctions: An application to golden rice. *American Journal of Agricultural Economics* 91(3): 837-853.

Costa ADA, Dekker M and Jongen WMF (2004) An overview of means-end theory: potential application in consumer-oriented food product design. *Trends in Food Science & Technology* 15(7-8): 403–415.

Costa ADA, Schoolmeester D, Dekker M, et al. (2007) To cook or not to cook: a means-end study of motives for choice of meal solutions. *Food Quality and Preference* 18(1): 77–88.

Cromwell E (1990) *Seed Diffusion Mechanisms in Small Farmer Communities: Lessons from Asia, Africa and Latin America*. London: ODI.

CtEH (2021) *Accelerating the delivery of quality seed from breeding investments made by the Crops to End Hunger (CtEH) initiative through economically sustainable seed systems*. White Paper commissioned by funders of the Crops to End Hunger (CtEH).

Darmon N and Drewnowski A (2008) Does social class predict diet quality?. *The American journal of clinical nutrition* 87(5): 1107-1117.

De Gregori TR (1987) Resources are not; they become: An institutional theory. *Journal of economic issues* 21(3): 1241-1263.

De Groote H, Kimenju SC, and Morawetz UB (2011) Estimating consumer willingness to pay for food quality with experimental auctions: the case of yellow versus fortified maize meal in Kenya. *Agricultural Economics* 42(1): 1-16.

Delaquis E, Kilwinger FBM, Slavchevska V, et al. (2021) *User guide to experimental auctions of vegetatively propagated seed.* CGIAR Research Program on Roots, Tubers and Bananas (RTB), RTB User Guide. No. 2021-7. Lima: RTB.

Delêtre M, Lett JM, Sulpice R, et al. (2021) Kinship networks of seed exchange shape spatial patterns of plant virus diversity. *Nature Communications* 12(1): 1–10.

DellaVigna S (2009) Psychology and economics: Evidence from the field. *Journal of Economic literature* 47(2): 315-72.

Dixon DF and Wilkinson IF (1984) An Alternative Paradigm for Marketing Theory. *European Journal of Marketing* 18(3): 40–50.

Donovan J, Rutsaert P, Mausch K, et al. (2021) Strengthening seed value chains: Persistent challenges and ways forward. Slide deck prepared as input for the One-CGIAR Strategy on Seed Systems Development. Available at: https://pimcgiarorg/cgiar-coe-seed-systems-development/references-and-outputs/ (Accessed 4 June 2021).

Dorward P, Craufurd P, Marfo K, et al. (2007) Improving Participatory Varietal Selection Processes: Participatory Varietal Selection and the Role of Informal Seed Diffusion Mechanisms for Upland Rice in Ghana. *Euphytica* 155: 315–327.

Doss CR (2006) Analyzing technology adoption using microstudies: limitations, challenges, and opportunities for improvement. *Agricultural economics* 34(3): 207-219.

Douglas JE (1980) *Successful seed programs. A planning and management guide*. Boulder: Westview Press.

Dray S and Dufour AB (2007) The ade4 package: Implementing the duality diagram for ecologists. *Journal of Statistical Software* 22(4): 1–20.

Drucker P (2012) *Management challenges for the 21st century*. London: Routledge.

Eberhard D (2017) Translating means-end research into advertising strategy using the meccas model. *Economia Agro-Alimentare* 19(3): 333–356.

Ellis F (1993) *Peasant economics: Farm households in agrarian development.* Cambridge: Cambridge University Press.

Etzioni A, Piore MJ and Streeck W (2010) *Behavioural economics. Socio-Economic Review* 8(2): 377-397.

Fitzgerald D (1993) Farmers deskilled: Hybrid corn and farmers' work. *Technology and Culture* 34(2): 324-343.

Fransella F, Bell R and Bannister D (2004) *A manual for repertory grid technique* (2nd ed.). Chichester: John Wiley & Sons.

Fu CS and Wu WY (2013) Means-end matrix and deduction in consumption behavior research. *Methodology* 9(2): 54–68.

Furnham A and Boo HC (2011) A literature review of the anchoring effect. *The journal of socio-economics* 40(1): 35-42.

Garrett KA (2021) Impact network analysis and the INA R package: Decision support for regional management interventions. *Methods in Ecology and Evolution* 00: 1–14.

Gengler CE, Klenosky DB and Mulvey MS (1995) Improving the graphic representation of means-end results. *International Journal of Research in Marketing* 12(3): 245–256.

Gepts P and Hancock J (2006) The future of plant breeding. *Crop Science* 46(4): 1630-1634.

Gharib MH, Palm-Forster LH, Lybbert TJ et al. (2021) Fear of fraud and willingness to pay for hybrid maize seed in Kenya. *Food Policy* 102: 102040.

Gibson JJ (2014) The theory of affordances. In Gibson JJ (eds) *The ecological approach to visual perception: classic edition.* New York: Psychology Press1 pp. 67-82.

Gibson JJ and Carmichael L (1966) *The senses considered as perceptual systems.* Boston: Houghton Mifflin.

Gibson RW, Mwanga ROM, Namanda S, et al. (2009) *Review of Sweetpotato Seed Systems in East and Southern Africa.* Integrated crop management program, Working Paper No. 2009-1. Lima: CIP

Giller KE, Andersson JA, Sumberg J, et al. (2017) A golden age for agronomy. In Sumberg J (eds) *Agronomy for development: The politics of knowledge in agricultural research*. London: Routledge, pp. 150-60.

Glover D, Sumberg J, Ton G, et al. (2019) Rethinking technological change in smallholder agriculture. *Outlook on Agriculture* 48(3): 169–180.

Gold CS, Karamura EB, Kiggundu A, et al. (1999) Geographic shifts in the highland cooking banana (Musa spp., group AAAEA) production in Uganda. *International Journal of Sustainable Development & World Ecology* 6(1): 45–59.

Gold CS, Kiggunda A, Karamura DA, et al. (2002) Selection Criteria of Musa Varieties through a Farmer Participatory Appraisal Survey in Uganda. *Experimental Agriculture* 38: 29–38.

Goodman LA (1961) Snowball sampling. *The annals of mathematical statistics* 32: 148–170.

Gower JC (1971) A general coefficient of similarity and some of its properties. *Biometrics* 27: 857–874.

Grum M, Gyasi EA, Osei C, et al. (2008). *Evaluation of Best Practices for Landrace Conservation: Farmer Evaluation.* Rome: Bioversity International.

Grunert KG (2010) Means-end chains–A means to which end? *Marketing: Journal of Research and Management* 6(1): 30–38.

Grunert KG (2019) International segmentation in the food domain: Issues and approaches. *Food Research International* 115: 311–318.

Grunert KG and Grunert SC (1995) Measuring subjective meaning structures by the laddering method: theoretical considerations and methodological problems. *International Journal of Research in Marketing* 12(3): 209–225.

Grunert KG, Beckmann SC and Sørensen E (2001) Means-end chains and laddering: An inventory of problems and an agenda for research. In Reynolds TJ and Olson JC (eds) *Understanding consumer decision making: The means-end approach to marketing and advertising strategy.* Mahwah: Lawrence Erlbaum Associates, pp. 64–91.

Grunert KG, Juhl HJ, Esbjerg L, et al. (2009) Comparing methods for measuring consumer willingness to pay for a basic and an improved ready made soup product. *Food Quality and Preference* 20(8): 607-619.

Guala F (2007). How to do things with experimental economics. In MacKenzie D, Muniesa F and Siu L (eds) *Do Economists Make Markets? On the Performativity of Economics.* Princeton: Princeton University Press, pp. 128-162.

Güth W, Ivanova-Stenzel R and Wolfstetter E (2005) Bidding behavior in asymmetric auctions: An experimental study. *European Economic Review* 49(7): 1891-1913.

Gutman J (1982) A means-end chain model based on consumer categorization processes. *The Journal of Marketing* 46: 60–72.

Hammond J, Fraval S, Van Etten J, et al. (2017) The rural household multi-indicator survey (RHoMIS) for rapid characterisation of households to inform climate smart agriculture interventions: Description and applications in east Africa and Central America. *Agricultural Systems* 151: 225–233.

Hammond J, Rosenblum N, Breseman D, et al. (2020) Towards actionable farm typologies: Scaling adoption of agricultural inputs in Rwanda. *Agricultural Systems* 183: 102857.

Hansson H and Lagerkvist CJ (2015) Identifying use and non-use values of animal welfare: evidence from Swedish dairy agriculture. *Food Policy* 50: 35–42.

Harari YN (2014) *Sapiens: A brief history of humankind.* New York: Penguin Random House.

Holm P (2007) Which way is up on Callon. In MacKenzie D, Muniesa F and Siu L (eds) *Do Economists Make Markets? On the Performativity of Economics.* Princeton: Princeton University Press, pp 225-243.

Huber J (1976) Ideal point models of preference. In B. B. Anderson (eds) *NA—Advances in consumer research Volume 03.* Cincinnati: Association for Consumer Research, pp. 138–142.

IITA (2015) Partners discuss management strategies for cassava diseases in Rwanda. IITA Bulletin, no. 2293, 15 September 2015. Available at: http://oar.icrisat.org/9146/1/IITA% 20Bulletin_2293LOWRES.pdf (accessed 18 August 2021).

Indimuli L (2013) *Factors Influencing the Discontinuance in Adoption of Tissue Culture Banana Technology: A Study of Smallholder Farmers in Maragwa District.* MSc thesis. Institute for Development Studies, University of Nairobi.

Inoue Y, Funk DC and McDonald H (2017) Predicting behavioral loyalty through corporate social responsibility: The mediating role of involvement and commitment. *Journal of Business Research* 75: 46–56.

Jacobsen K, Omondi BA, Almekinders CJM, et al. (2019) Seed degeneration of banana planting materials: strategies for improved farmer access to healthy seed. *Plant Pathology* 68(2): 207–228.

Jan PT, Lu HP and Chou TC (2012) Measuring the perception discrepancy of the service quality between provider and customers in the Internet Protocol Television industry. *Total Quality Management and Business Excellence* 23(7-8): 981–995.

Jolliffe IT (2002) Principal components in regression analysis. In: *Principal Component Analysis. Springer Series in Statistics.* New York: Springer. pp 167–198.

Jonassen DH (1991) Objectivism versus constructivism: Do we need a new philosophical paradigm?. *Educational technology research and development* 39(3): 5-14.

Kabunga NS, Dubois T and Qaim M (2012a) Yield effects of tissue culture bananas in Kenya: accounting for selection bias and the role of complementary inputs. *Journal of Agricultural Economics* 63(2): 444–464.

Kabunga NS, Dubois T and Qaim M (2012b) Heterogeneous information exposure and technology adoption: the case of tissue culture bananas in Kenya. *Agricultural Economics* 43(5): 473–486.

Kaciak E and Cullen CW (2006) Analysing means-end chain data in marketing research. *Journal of Targeting, Measurement, and Analysis for Marketing* 15(1): 12–20.

Kahneman D, Ritov I, Jacowitz KE, et al. (1993) Stated willingness to pay for public goods: A psychological perspective. *Psychological science* 4(5): 310-315.

Kanbur R and Shaffer P (2007) Epistemology, normative theory and poverty analysis: implications for Q-squared in practice. *World Development* 35(2): 183-196.

Karamura DA, Karamura EB and Tinzaara W (2012) *Banana Cultivar Names, Synonyms and Their Usage in Eastern Africa*. Kampala: Bioversity International.

Karamura EB, Turyagyenda FL, Tinzaara W, et al. (2008) *Xanthomonas Wilt of Bananas in East and Central Africa: Diagnostic and Management Guide*. Kampala: Bioversity International.

Kasente D, Lockwood M, Vivian J, et al. (2002) Gender and the expansion of non-traditional agricultural exports in Uganda. In: Razavi S (eds) *Shifting Burdens, Gender and Agrarian Change Under Neoliberalism.* Sterling: Kumarian Press, pp. 35–65.

Kawuki SR, Kaweesi T, Esuma W, et al. (2016) Eleven years of breeding efforts to combat cassava brown streak disease. *Breeding Science* 66(4): 560–571.

Keleman A, Hellin J and Bellon MR (2009) Maize Diversity, Rural Development Policy, and Farmers' Practices: Lessons from Chiapas, Mexico. *The Geographical Journal* 175 (1): 52–70

Kelly GA (1955) *The Psychology of Personal Constructs.* New York: Norton.

Kikulwe E (2016) Banana Tissue Culture: Community Nurseries for African Farmers. In Andrade-Piedra J, Bentley JW, Almekinders CJM, et al. (eds) *Case Studies of Roots, Tubers and Bananas Seed Systems.* CGIAR Research Program on Roots, Tubers and Bananas (RTB), Working Paper No. 2016-3. Lima: RTB.

Kilwinger FBM and Buddenhagen CE (2021). *User guide to seed tracing.* CGIAR Research Program on Roots, Tubers and Bananas (RTB), RTB User Guide. No. 2021-1. Lima: RTB.

Kilwinger FBM, Marimo P, Rietveld AM, et al. (2020a) Application of the means-end chain analysis to understand farmers' perceptions of banana seed sources in central and Western Uganda: the full data set.

Kilwinger FBM, Marimo P, Rietveld AM, et al. (2020b) Not only the seed matters: Farmers' perceptions of sources for banana planting materials in Uganda. *Outlook on Agriculture* 49(2): 119–132.

Kilwinger FBM, Rietveld AM and Almekinders CJM (2017) *The culture of banana cultivation: an exploratory study of a local banana seed system in central Uganda.* CGIAR Research Program on Roots, Tubers and Bananas (RTB), Working Paper No. 2017-1. Lima: RTB

Kilwinger FBM, Rietveld AM and Almekinders CJM (2019a) *A comparative study on banana seed systems in Mbarara district, Western Uganda and Mukono district, Central Uganda.* CGIAR Research Program on Roots, Tubers and Bananas (RTB), Working Paper No. 2019-4. Lima: RTB

Kilwinger FBM, Rietveld AM, Groot JCJ, et al. (2019b) Culturally embedded practices of managing banana diversity and planting material in central Uganda. *Journal of Crop Improvement* 33(4): 456–477.

Klenosky DB (2002) The "pull" of tourism destinations: A means-end investigation. *Journal of Travel Research* 40(4): 385–395.

Klerkx L, Van Mierlo B and Leeuwis C (2012) Evolution of systems approaches to agricultural innovation: concepts, analysis and interventions. In: Darnhofer I, Gibbon D and Dedieu B (eds) *Farming Systems Research Into the 21st Century: The new Dynamic.* Dordrecht: Springer, pp. 457–483.

Kloppenburg JR (1988) *First the Seed: The Political Economy of Plant Biotechnology*. Cambridge: Cambridge University Press.

Knowler D and Bradshaw B (2007) Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food policy* 32(1): 25-48.

Krupnik TJ, Andersson JA, Rusinamhodzi L, et al. (2019) Does size matter? a critical review of meta-analysis in agronomy. *Experimental agriculture* 55(2): 200-229.

Kubiriba J and Tushemereirwe WK (2014) Approaches for the control of banana Xanthomonas wilt in east and central Africa. *African Journal of Plant Science* 8(8): 398–404.

Kuivanen KS, Alvarez S, Michalscheck M, et al. (2016) Characterising the diversity of smallholder farming systems and their constraints and opportunities for

innovation: A case study from the northern region, Ghana. *NJAS-Wageningen Journal of Life Sciences* 78: 153–166.

Lagerkvist CJ, Ngigi M, Okello JJ, et al. (2012) Means-End Chain approach to understanding farmers' motivations for pesticide use in leafy vegetables: The case of kale in peri-urban Nairobi, Kenya. *Crop Protection* 39: 72–80.

Lancaster KJ (1966) A new approach to consumer theory. *Journal of Political Economy* 74(2): 132–157.

Lastovicka JL (1995) Review: LADDERMAP-VERSION 4.0 by Chuck Gengler. *Journal of Marketing Research* 32(4): 494–496.

Latour B (1987) *Science in action: How to follow scientists and engineers through society.* Cambridge: Harvard university press.

Latour B and Woolgar S (1986) *Laboratory life.* Princeton: Princeton University Press

Law J (2004) *After method: Mess in social science research*. London: Routledge.

Law J (2009) Seeing like a survey. *Cultural sociology* 3(2): 239-256

Law J and Mol A (2001) Situating technoscience: an inquiry into spatialities. *Environment and planning D: society and space* 19(5): 609-621

Law J, Ruppert E and Savage M (2011) *The double social life of methods*. Centre for Research on Socio-Cultural Change (CRESC), Working Paper No 95.

Leeuwis C (2022) The conundrum of articulating scientific knowledge and technology demand. In Ludwig D, Boogaard B, Macnaghten P et al. (eds) *The politics of knowledge in inclusive development and innovation.* London and New York: Routledge, pp 269-282.

Leeuwis C and Aarts N (2021) Rethinking adoption and diffusion as a collective social process: towards an interactional perspective. In Campos H (eds) *The Innovation revolution in agriculture - A roadmap to value creation*. Cham: Springer press, pp. 95-116.

Legg JP, Jeremiah SC, Obiero HM, et al. (2011) Comparing the regional epidemiology of the cassava mosaic and cassava brown streak virus pandemics in Africa. *Virus Research* 159(2): 161–170.

Legg JP, Okao-Okuja G, Mayala R, et al. (2001) Spread into Rwanda of the severe cassava mosaic virus disease pandemic and the associated Uganda variant of East African cassava mosaic virus (EACMV-Ug). *Plant Pathology* 50(6): 796.

Leppard P, Russell CG and Cox DN (2003) Improving means-end- chain studies by using a ranking method to construct hierarchical value maps. *Food Quality and Preference* 15: 489–497.

Linnemann AR and de Bruijn GH (1987) Traditional seed supply for food crops. LEISA: *ILEIA newsletter for low-external-input and sustainable agriculture* 3(2): 10-11.

Longley CA (2000) *A social life of seeds: local management of crop variability in North-Western Sierra Leone*. PhD thesis. University of London.

Lopez-Ridaura S, Frelat R, van Wijk MT, et al. (2018) Climate smart agriculture, farm household typologies and food security: An ex-ante assessment from eastern India. *Agricultural Systems* 159: 57–68.

Louwaars NP and De Boef WS (2012) Integrated seed sector development in Africa: A conceptual framework for creating coherence between practices, programs, and policies. *Journal of Crop Improvement* 26(1): 39–59.

Lusk JL and Hudson D (2004) Willingness-to-pay estimates and their relevance to agribusiness decision making. *Applied Economic Perspectives and Policy* 26(2): 152-169.

Lusk JL and Shogren JF (2007) *Experimental Auctions: Methods and Applications in Economic and Marketing Research*. Cambridge: Cambridge University Press.

Lusk JL, Alexander C and Rousu MC (2007) Designing experimental auctions for marketing research: The effect of values, distributions, and mechanisms on incentives for truthful bidding. *Review of Marketing Science* 5(1): 1-30.

Lusk JL, Feldkamp T and Schroeder TC (2004) Experimental auction procedure: impact on valuation of quality differentiated goods. *American Journal of Agricultural Economics* 86(2): 389-405.

Lwandasa H, Kagezi GH, Akol AM, et al. (2014) Assessment of Farmers' Knowledge and Preferences for Planting Materials to Fill-Gaps in Banana Plantations in Southwestern Uganda. *Uganda Journal of Agricultural Sciences* 15(2): 165–178.

MacKenzie D, Muniesa F and Siu L (2007) *Introduction to Do Economists Make Markets? On the Performativity of Economics.* Princeton: Princeton University Press.

Maggidi IM (2019) *Cassava Value Chain: Willingness To Pay for Improved Cassava Planting Material in Coastal and Lake Victoria areas of Tanzania.* MSc Thesis. Sokoine University of Agriculture, Tanzania.

Manyong VM, Dixon AGO, Makinde KO, et al. (2000) *The contribution of IITA-improved cassava to food security in sub-Saharan Africa: An impact study.* Ibadan: IITA.

Maredia MK, Shupp R, Opoku E, et al. (2019) Farmer perception and valuation of seed quality: Evidence from bean and cowpea seed auctions in Tanzania and Ghana. *Agricultural Economics* 50(4): 495–507.

Maskin E and Riley J (2000) Asymmetric auctions. *The review of economic studies* 67(3): 413-438.

Mastenbroek A, Sirutyte I and Sparrow R (2021) Information Barriers to Adoption of Agricultural Technologies: Willingness to Pay for Certified Seed of an Open Pollinated Maize Variety in Northern Uganda. *Journal of Agricultural Economics* 72(1): 180-201.

Mausch K, Almekinders CJM, Hambloch C, et al. (2021) Putting diverse farming households' preferences and needs at the centre of seed system development. *Outlook on Agriculture* 50(4): 356-365.

Maxwell JA (2004) Causal explanation, qualitative research, and scientific inquiry in education. *Educational researcher* 33(2): 3-11.

McAfee RP and McMillan J (1987) Auctions and bidding. *Journal of economic literature* 25(2): 699-738.

McEwan MA, Almekinders CJM, Andrade-Piedra JJ, et al. (2021) Breaking through the 40% adoption ceiling: Mind the seed system gaps. A perspective on seed systems research for development in One CGIAR. *Outlook on Agriculture* 50(1): 5-12.

McGuire SJ (2008) Securing access to seed: Social relations and sorghum seed exchange in eastern Ethiopia. *Human Ecology* 36(2): 217–229.

McGuire SJ and Sperling L (2016) Seed systems smallholder farmers use. *Food Security* 8(1): 179–195.

MECAnalyst (nd) Cognitive consumer mapping software user guide rev. 0.4_en. MECanalyst – Skymax-DG.

Mendola M (2007) Farm Household Production Theories: A Review of`Institutional" and ``Behavioral" Responses. *Asian Development Review* 24(1): 49.

Merfeld K, Wilhelms MP and Henkel S (2019) Being driven autonomously—A qualitative study to elicit consumers' overarching motivational structures. Transportation Research Part C: *Emerging Technologies* 107: 229–247.

Mirman D, Landrigan JF and Britt AE (2017) Taxonomic and thematic semantic systems. *Psychological Bulletin* 143(5): 499–520.

Moore WL (1982) Predictive power of joint space models constructed with composition techniques. *Journal of Business Research* 10(2): 217–236.

Morawetz UB, De Groote H and Kimenju SC (2011) Improving the use of experimental auctions in Africa: Theory and evidence. Journal of Agricultural and *Resource Economics* 36(2): 263-279.

Morduch J (1995) Income smoothing and consumption smoothing. *Journal of Economic Perspectives* 9(3): 103–114.

Morgan SN, Mason NM and Maredia MK (2020) Lead-farmer extension and smallholder valuation of new agricultural technologies in Tanzania. *Food Policy* 97: 101955.

Mort GS and Rose T (2004) The effect of product type on value linkages in the means-end chain: implications for theory and method. *Journal of Consumer Behaviour: An International Research Review* 3(3): 221–234.

Morton JF (2007) The Impact of Climate Change on Smallholder and Subsistence Agriculture. Proceedings of the National Academy of Sciences 104(50): 19680–19685.

Mueller DC (2004) Models of man: neoclassical, behavioural, and evolutionary. *Politics, Philosophy & Economics* 3(1): 59-76.

Mulugo L, Kyazze FB, Kibwika P, et al. (2019) Unravelling technology-acceptance factors influencing farmer use of banana tissue culture planting materials in central Uganda. *African Journal of Science, Technology, Innovation and Development* 11: 1–13.

Mulumba JW, Nkwiine C, Male-Kayiwa B, et al. (2004) *Evaluation of farmers' best practices for on-farm conservation of rare banana cultivars in the semi-arid region of Lwengo sub-county, Uganda*. Uganda Journal of Agricultural Sciences 9(1): 281-288.

Murongo M, Wangai KJ, Mwine TJ, et al. (2019) Farmer-based dynamics in tissue culture banana technology adoption: a socio-economic perspective among small holder farmers in uganda. *African Journal of Agricultural Research* 13: 2836–2854.

Muyanga M (2009) Smallholder adoption and economic impacts of tissue culture banana in kenya. *African Journal of Biotechnology* 8: 6548–6555.

Mwiti F, Okello JJ and Munei K (2015) *Are Farmers Willing to Pay for Quality Planting Materials of Clonally Propagated Biofortified Crops? The Case of Orange-Fleshed Sweetpotatoe in Tanzania.* International Association of Agricultural Economists. Milan, 9-14 August 2015.

Nalley LL, Hudson D and Parkhurst GM (2006) Consistency of consumer valuation under different information sets: An experimental auction with sweet potatoes. *Journal of Food Distribution Research* 37: 56-67.

Namanda S, Gibson RW and Sindi K (2011) Sweetpotato seed systems in Uganda, Tanzania, and Rwanda. *Journal of Sustainable Agriculture* 35: 870–884.

Naspetti S and Zanoli R (2004) Do consumers care about where they buy organic products? A means-end study with evidence from Italian data. In G. Baourakis (eds) *Marketing trends for organic food in the 21st century*. Singapore: World Scientific Publishing Co. Pte. Ltd, pp. 239–255.

Navarrete I, López V, Borja R, et al. (2022) Variety and on-farm seed management practices affect potato seed degeneration in the tropical highlands of Ecuador. *Agricultural Systems* 198: 103387.

Nazarea VD (2006) *Cultural memory and biodiversity*. Arizona: University of Arizona Press.

Neate PJ and Guei RG (2010) *Promoting the growth and development of smallholder seed enterprises for food security crops: best practices and options for decision making*. Rome: Food and Agriculture Organization of the United Nations (FAO).

Neisser U (1976) *Cognition and reality: Principles and implications of cognitive psychology*. New York: W.H. Freeman.

Ngigi MW, Muëller U and Birner R (2018) Farmers' intrinsic values for adopting climate-smart practices in Kenya: empirical evidence from a means-end chain analysis. *Climate and Development* 10(7): 614–624.

Night G, Asiimwe P, Gashaka G, et al. (2011) Occurrence and distribution of cassava pests and diseases in Rwanda. *Agriculture, Ecosystems & Environment* 140(3–4): 492–497.

Nitturkar H (2018) "All or None" Approach to Developing a Cassava Seed System in Nigeria. Marketlinks, 22 August, 2018. Available at: https://

www.marketlinks.org/blogs/ all-or-none-approach-developing-cassava-seed-system-nigeria (Accessed 4 June 2021).

Nyanga PH (2012) Factors influencing adoption and area under conservation agriculture: A mixed methods approach. *Sustainable Agriculture Research* 1(2): 27-40.

Okello JJ, Lagerkvist CJ, Kakuhenzire R, et al. (2018) Combining means-end chain analysis and goal-priming to Analyze Tanzanian farmers' motivations to invest in quality seed of new potato varieties. *British Food Journal* 120(7): 1430–1445.

Okello JJ, Zhou Y, Barker I, et al. (2019). Motivations and Mental Models Associated with Smallholder Farmers' Adoption of Improved Agricultural Technology: Evidence from Use of Quality Seed Potato in Kenya. *The European Journal of Development Research* 31(2): 271–292.

Okonya SJ, Ocimati W, Nduwayezu A, et al. (2019) Farmer reported pest and disease impacts on root, tuber, and banana crops and livelihoods in Rwanda and Burundi. *Sustainability* 11: 1592.

Okumu OO, Rajendran S, Okello J et al. (2021) *Farmers' demand for quality and nutritionally enhanced sweetpotato planting material: Evidence from experimental auctions in Rwanda.* CIP, Working paper no 2021-3 Report. Lima: CIP.

Olson JC and Reynolds TJ (2001) The means–end approach to understanding consumer decision making. In Reynolds TJ and Olson JC (eds) *Understanding consumer decision making: The means-end approach to marketing and advertising strategy.* Mahwah: Lawrence Erlbaum Associates, pp. 3–19

OpenStreetMap (2018) contributors, Jarry1250, NordNordWest/Wikipedia. Available at: https://en.wikipedia.org/wiki/Mukono_District#/media/File:Mukono_District_in_Uganda.svg (Accessed 16 January 2019).

Oxfam Novib (2021). Oxfam Novib's comments on the Crops to End Hunger White Paper on Economically Sustainable Seed Systems. Available at:

https://sdhsprogram.org/oxfam-novibs-comments-on-the-crops-to-end-hunger-white-paper-on-economically-sustainable-seed-systems/ (Accessed 14 March 2022).

Pannell DJ, Marshall GR, Barr N, et al. (2006) Understanding and promoting adoption of conservation practices by rural landholders. *Australian Journal of Experimental Agriculture* 46(11): 1407-1424.

Park YS, Konge L and Artino AR (2020) The positivism paradigm of research. *Academic Medicine* 95(5): 690-694.

Patil LB, Legg PJ, Kanju E, et al. (2015) Cassava brown streak disease: A threat to food security. *Africa Journal of General Virology* 96: 956–968.

Patrick K and Xu Y (2018) Exploring Generation Y consumers' fitness clothing consumption: A means-end chain approach. Journal of Textile and Apparel, *Technology and Management* 10(3): 1–15.

Pautasso M, Aistara G, Barnaud A, et al. (2013) Seed exchange networks for agrobiodiversity conservation. A review. *Agronomy for Sustainable Development* 33(1): 151–175.

Peach WN and Constantin JA (1972) *Zimmermann's World resources and industries.* (3rd ed.) New York: Harper & Row.

Peirce CS (1878). Illustrations of the logic of science: Second paper— how to make our ideas clear. *The Popular Science Monthly* 12: 286–302.

Pellegrini L and Tasciotti L (2014) Crop diversification, dietary diversity and agricultural income: empirical evidence from eight developing countries. *Canadian Journal of Development Studies* 35(2): 211–227.

Pezanis-Christou P (1995) *Experimental results in asymmetric auctions, the 'low-ball' effect.* EUI Working Paper ECO No. 95/1.

Pezeshki F, Ardekani SS, Khodadadi M, et al. (2019) Cognitive structures of Iranian senior tourists towards domestic tourism destinations: A means-end chain approach. *Journal of Hospitality and Tourism Management* 39: 9–19.

Phillips JM and Reynolds TJ (2009) A hard look at hard laddering: a comparison of studies examining the hierarchical structure of means-end theory. *Qualitative Market Research: An International Journal* 12(1): 83–99.

Pircher T, and Almekinders CJM (2021) Making sense of farmers' demand for seed of root, tuber and banana crops: a systematic review of methods. *Food Security* 13(5): 1285-1301.

Pircher T, Obisesan D, Nitturkar H, et al. (2019) *Characterizing Nigeria's cassava seed system and the use of planting material in three farming communities*. CGIAR ResearchProgram on Roots, Tubers and Bananas (RTB), Working Paper No. 2019-1. Lima: RTB.

Plant KL and Stanton NA (2013) The explanatory power of Schema Theory: theoretical foundations and future applications in Ergonomics. *Ergonomics* 56(1): 1–15.

Poire MK (2010) From bounded rationality to behavioural economics. *Socio-Economic Review* 8(2): 377-397.

Pretty J (2002) *Agri-Culture: Reconnecting People, Land and Nature.* London: Earthscan.

Putler DS (1992) Incorporating reference price effects into a theory of consumer choice. *Marketing science* 11(3): 287-309.

R Core Team (2019) R: *A language and environment for statistical computing.* Vienna: R Foundation for Statistical Computing

Rachkara P, Phillips DP, Kalule SW, et al. (2017) Innovative and beneficial informal sweetpotato seed private enterprise in northern Uganda. *Food Security* 9(3): 595–610.

Ratneshwar S, Barsalou LW, Pechmann C, et al. (2001) Goal- derived categories: The role of personal and situational goals in category representations. *Journal of Consumer Psychology* 10(3):147–157.

Reynolds A, Richards G, De la Iglesia B, et al. (1992) Clustering rules: A comparison of partitioning and hierarchical clustering algorithms. *Journal of Mathematical Modelling and Algorithms* 5: 475–504.

Reynolds TJ and Gutman J (1988) Laddering theory, method, analysis, and interpretation. *Journal of Advertising Research* 28(1): 11–31.

Reynolds TJ and Gutman J (2001) Laddering theory, method, analysis, and interpretation. In Reynolds TJ and Olson JC (eds) *Understanding consumer decision making: The means-end approach to marketing and advertising strategy.* Mahwah: Lawrence Erlbaum Associates, pp. 24–63.

Reynolds TJ and Olson JC (2001) Theoretical perspectives for means- end research - section overview. In Reynolds TJ and Olson JC (eds) *Understanding consumer decision making: The means-end approach to marketing and advertising strategy.* Mahwah: Lawrence Erlbaum Associates, pp. 358–359.

Reynolds TJ and Phillips JM (2009) A review and comparative analysis of laddering research methods: Recommendations for quality metrics. *Review of Marketing Research* 5: 130–174.

Ricciardi V (2015) Social seed networks: identifying central farmers for equitable seed access. *Agricultural Systems* 139: 110-121.

Rietveld AM (2017) Gender Norms and Agricultural Innovation: Insights from Uganda Sustainable Intensification in Smallholder Agriculture: An Integrated Systems Research Approach. In Oborn I, Vanlauwe B, Phillips M, et al. (eds) *Sustainable Intensification in Smallholder Agriculture. An Integrated Systems Research Approach.* London: Earthscan, pp. 289–303

Rietveld AM and Farnworth CR (2018) *Towards Gender Responsive Banana Research for Development in the East-African Highlands: GENNOVATE Resources for Scientists and Research Teams.* Mexico: CIMMYT

Rietveld AM, Ajambo S and Kikulwe E (2016) *Economic Gain and Other Losses? Gender Relations and Matooke Production in Western Uganda*. Tropentag, Vienna, 18–21 September 2016.

Rietveld AM, Jogo W, Mpiira S, et al. (2014) The effect of banana Xanthomonas wilt on beer-banana value chains in central Uganda. *Journal of Agribusiness in Developing and Emerging Economies* 4(2): 172–184.

Rietveld AM, Van der Burg M and Groot JCJ (2020) Bridging youth and gender studies to analyse rural young women and men's livelihood pathways in central Uganda. *Journal of Rural Studies* 75: 152–163.

Robinson JC (1996) *Bananas and Plantains.* Wallingford: CAB international.

Robinson JC and Nel DJ (1990) Competitive Inhibition of Yield Potential in a 'Williams' Banana Plantation Due to Excessive Sucker Growth. *Scientia Horticulturae* 43: 225–236.

Rogers EM and Ban A (1963) Research on the diffusion of agricultural innovations in the United States and the Netherlands. *Sociologia Ruralis* 3(1): 38-49.

Rohrbach DD, Mashingaidze AB and Mudhara M (2005) *Distribution of Relief Seed and Fertilizer in Zimbabwe: Lessons From the 2003/04 Season.* Bulawayo: ICRISAT and Rome: FAO.

Rokeach M (1973) *The nature of human values.* New York: Free Press.

Ronda L, Valor C and Abril C (2018) Are they willing to work for you? An employee-centric view to employer brand attractiveness. *Journal of Product and Brand Management* 27(5): 573–596.

Ronner E, Almekinders CJM, and van Heerwaarden J (2016) Tracing Seed Diffusion from Introduced Legume Seeds through N2Africa Demonstration Trials and Seed-

Input Packages. Available at: https://n2africa.org/sites/default/files/Tracing%20seed%20diffusion%20from%20introduced%20legume%20seeds%20through%20N2Africa %20demonstration%20trials%20and%20seed-input%20packages.pdf (Accessed 6 February 2019).

Roots, Tubers and Bananas (2020) Available at: https://www.rtb.cgiar.org/ (Accessed 14 March 2022)

Rosen S (1974) Hedonic prices and implicit markets - product differentiation in pure competition. *Journal of Political Economy* 82(1): 34–55.

Rosenzweig C, Iglesias A, Yang XB, et al. (2001) Climate Change and Extreme Weather Events: Implications for Food Production, Plant Diseases, and Pests. *Global Change and Human Health* 2(2): 90–104.

Rothkopf MH and Harstad RM (1994) Modeling competitive bidding: A critical essay. *Management Science* 40(3): 364-384.

Rousu MC (2015) Fifteen years of experimental auctions of GM foods: what have we learned about policy, preferences, and auction design? *AgBioForum* 18(3): 320-326

Roy R, Rabbanee FK and Sharma P (2016). Exploring the interactions among external reference price, social visibility and purchase motivation in pay-what-you-want pricing. *European Journal of Marketing* 50(5/6): 816-837.

Ruzzante S, Labarta R and Bilton A (2021) Adoption of agricultural technology in the developing world: A meta-analysis of the empirical literature. *World Development* 146: 105599.

SAFCEI (2021). Open letter to the Bill and Melinda Gates Foundation from the SAFCEI and faith community representatives from the African continent. SAFCEI, 10 September 2020. Available at: https://safcei.org/wp-content/uploads/2020/09/Gates-Foundation-appeal-from-SAFCEI-African-faith-Leaders-September-2020.docx.pdf (Accessed 14 March 2022).

Salame N, Pugliese P and Naspetti S (2016) Motivation and values of farmers in Lebanon: A comparison between organic and conventional agricultural producers.

New Medit: Mediterranean Journal of Economics, Agriculture and Environment 15(2): 70–80.

Sandmo A (1999) Asymmetric information and public economics: The Mirrlees-Vickrey Nobel prize. *Journal of Economic Perspectives* 13(1): 165-180.

Sartas M, Schut M, Proietti C, et al. (2020) Scaling Readiness: Science and practice of an approach to enhance impact of research for development. *Agricultural Systems* 183: 102874.

Schlegel RHJ (2003) *Encyclopedic dictionary of plant breeding and related subjects.* New York: Food Products Press.

Scoones I and Thompson J (2011) The politics of seed in Africa's green revolution: Alternative narratives and competing pathways. *ids Bulletin* 42(4): 1-23.

Scott WA (1969) Structure of natural cognitions. *Journal of Personality and Social Psychology* 12: 261–278.

Shirima RR, Maeda DG, Kanju EE, et al. (2019) Assessing the degeneration of cassava under high-virus inoculum conditions in coastal Tanzania. *Plant Disease* 103(10): 2652–2664.

Shogren JF, Fox JA, Hayes DJ, et al. (1994) Bid sensitivity and the structure of the Vickrey auction. *American Journal of Agricultural Economics* 76(5): 1089-1095.

Simon HA (1972) Theories of bounded rationality. *Decision and Organization* 1(1): 161-176.

Sperling L (2002) Emergency seed aid in Kenya: some case study insights on lessons learned during the 1990s. *Disasters* 26(4): 329–342.

Sperling L and Loevinsohn ME (1993) The Dynamics of Adoption: Distribution and Mortality of Bean Varieties among Small Farmers in Rwanda. *Agricultural Systems* 41: 441–453.

Sperling L, Boettiger S and Barker I (2013) *Integrating seed systems.* AgPartnerXChange, Planning for scale brief no. 3.

Sperling L, Cooper HD and Remington T (2008) Moving towards more effective seed aid. *The Journal of Development Studies* 44(4): 586–612.

Spielman DJ and Smale M (2017) *Policy options to accelerate variety change among smallholder farmers in South Asia and Africa South of the Sahara.* IFPRI, Discussion Paper 01666.

Staver C, Van den Bergh I, Karamura E, et al. (2010) Targeting actions to improve the quality of farmer planting material in bananas and plantains - building a national priority-setting framework. *Tree and Forestry Science and Biotechnology* 4(1): 1–10.

Steenkamp JBE and Van Trijp HCM (1997) Attribute elicitation in marketing research: A comparison of three procedures. *Marketing Letters* 8(2): 153–165.

Stone GD (2007) Agricultural deskilling and the spread of genetically modified cotton in Warangal. *Current Anthropology* 48(1): 67–103.

Stone GD and Flachs A (2014) The problem with the farmer's voice. *Agriculture and Human Values* 31(4): 649-653.

Storkerson P (2010) Naturalistic cognition: A research paradigm for human-centered design. *Journal of Research Practice* 6(2): 1–23.

Streeck W (2010) Does 'behavioural economics' offer an alternative to the neoclassical paradigm? *Socio-Economic Review* 8(2): 377-397.

Stuart E, Asfaw A, Adebola P (2021) Yam seed system characteristics in Nigeria: local practices, preferences, and the implications for breeding and seed sector improvement. *Outlook on Agriculture* 50(4): 455-467

Subedi AP, Chaudhary BK, Baniya RB, et al. (2003) Who Maintains Crop Genetic Diversity and How?: Implications for On-Farm Conservation and Utilization. *Journal of Culture and Agriculture* 25(2): 41–50.

Tadesse Y, Almekinders CJ, Schulte RP, et al. (2017) Tracing the seed: seed diffusion of improved potato varieties through farmers' networks in Chencha, Ethiopia. *Experimental Agriculture* 53(4): 481–496.

Tenkouano A, Hauser S, Coyne D, et al. (2006) Clean Planting Materials and Management Practices for Sustained Production of Banana and Plantain in Africa. *Chronica Horticulturae* 46(2): 14–18.

Ter Hofstede F, Audenaert A, Steenkamp JBE, et al. (1998) An investigation into the association pattern technique as a quantitative approach to measuring means-end chains. *International Journal of Research in Marketing* 15(1): 37–50.

Ter Hofstede F, Steenkamp JBE and Wedel M (1999) International market segmentation based on consumer-product relations. *Journal of Marketing Research* 36(1): 1–17.

Tey YS, Arsil P, Brindal M, et al. (2015) A means-end chain approach to explaining the adoption of good agricultural practices certification schemes: the case of Malaysian vegetable farmers. *Journal of Agricultural and Environmental Ethics* 28(5): 977–990.

Thiele G (1999) Informal potato seed systems in the Andes: Why are they important and what should we do with them? *World Development* 27(1): 83–99.

Thiele G, Dufour D, Vernier P, et al. (2021) A review of varietal change in roots, tubers and bananas: consumer preferences and other drivers of adoption and implications for breeding. *International Journal of Food Science & Technology* 56(3): 1076-1092.

Thomas-Sharma S, Abdurahman A, Ali S, et al. (2016) Seed degeneration in potato: the need for an integrated seed health strategy to mitigate the problem in developing countries. *Plant Pathology* 65(1): 3–16.

Thomas-Sharma S, Andrade-Piedra J, Carvajal Yepes M, et al. (2017) A risk assessment framework for seed degeneration: Informing an integrated seed health strategy for vegetatively propagated crops. *Phytopathology* 107(10): 1123–1135.

Thrupp LA (2000) Linking agricultural biodiversity and food security: The valuable role of agrobiodiversity for sustainable agriculture. *International Affairs* 76(2): 265–281.

Tinzaara W, Karamura E, Blomme G, et al. (2013). Why sustainable management of xanthomonas wilt of banana in east and central Africa has been elusive. *Acta Horticulturae* 986: 157–164.

Tobi H and Kampen JK (2018) Research design: the methodology for interdisciplinary research framework. *Quality & Quantity* 52(3): 1209-1225.

Tolman EC and Brunswik E (1935) The organism and the causal texture of the environment. *Psychological Review* 42(1): 43–77.

Tripp R (1996) Biodiversity and Modern Crop Varieties: Sharpening the Debate. *Agriculture and Human Values* 13(4): 48–63.

Tripp R (2003) *How to cultivate a commercial seed sector*. Symposium on Sustainable Agriculture. Bamako, 1-5 December 2003.

Tripp R and Rohrbach D (2001) Policies for African seed enterprise development. *Food Policy* 26(2): 147–161.

Tsegaye B and Berg T (2007) Genetic Erosion of Ethiopian Tetraploid Wheat Landraces in Eastern Shewa, Central Ethiopia. *Genetic Resources and Crop Evolution* 54: 715–726.

Tumwegamire S, Kanju E, Legg J, et al. (2018) Exchanging and managing in-vitro elite germplasm to combat cassava brown streak disease (CBSD) and cassava mosaic disease (CMD) in Eastern and Southern Africa. *Food Security* 10(2): 351–368.

Tversky A and Kahneman D (1974) Judgment under uncertainty: Heuristics and biases. *Science* 185(4157): 1124-1131.

Uganda Bureau of Statistics (UBOS) (2010) *Uganda Census of Agriculture 2008/2009. Volume iv: Crop Area and Production Report.* Kampala: UBOS

Uganda Bureau of Statistics (UBOS) (2014) *The National Population and Housing Census 2014 – Area Specific Profile Series.* Kampala: UBOS.

United Nations General Assembly (2015) *Transforming Our World: The 2030 Agenda for Sustainable Development.* United Nations Sustainable Development Summit, New York 25-27 September 2015.

Urrea-Hernandez C, Almekinders CJM and Van Dam YK (2016) Understanding perceptions of potato seed quality among small-scale farmers in Peruvian highlands. *NJAS Wageningen Journal of Life Sciences* 76: 21–28.

USAID (2010) Time to Learn: an evaluation strategy for revitalized foreign assistance. Available at: http://pdf.usaid.gov/pdf_docs/Pnadw234.pdf (Accessed 15 March 2022).

Valette-Florence P (1998) A causal analysis of means-end hierarchies in a cross-cultural context: methodological refinements. *Journal of Business Research* 42(2): 161–166.

Valette-Florence P and Rapacchi B (1991) Improvements in means-end chain analysis. *Journal of Advertising Research* 31(1): 30–45.

Van Dam YK and van Trijp HC (2013) Relevant or determinant: Importance in certified sustainable food consumption. *Food Quality and Preference* 30(2): 93–101.

Van Ittersum K, Pennings JM, Wansink B, et al. (2007) The validity of attribute-importance measurement: *A review. Journal of Business Research* 60(11): 1177–1190.

Van Niekerk J and Wynberg R (2017) Traditional seed and exchange systems cement social relations and provide a safety net: a case study from Kwazulu-Natal, South Africa. *Agroecology and Sustainable Food Systems* 41(9-10): 1099–1123.

Van Rekom J and Wierenga B (2007) On the hierarchical nature of means-end relationships in laddering data. *Journal of Business Research* 60(4): 401–410.

Vanden Abeele V and Zaman B (2009) *Laddering the user experience!* User Experience Evaluation Methods in Product Development Workshop. Uppsala, 24-18 August 2009.

Vanden Abeele V, Hauters E and Zaman B (2012) *Increasing the reliability and validity of quantitative laddering data with LadderUX.* CHI′12 Extended Abstracts on Human Factors in Computing Systems. Austin, 5-10 May 2012.

Vargo SL, and Lusch RF (2004) Evolving to a new dominant logic for marketing. *Journal of Marketing* 68(1): 1–17.

Verburg RM, Bosch-Sijtsema P and Vartiainen M (2013) Getting it done: Critical success factors for project managers in virtual work settings. *International Journal of Project Management* 31(1): 68–79.

Vickrey W (1961) Counterspeculation, auctions, and competitive sealed tenders. *The Journal of Finance* 16(1): 8-37.

Villa TCC, Maxted N, Scholten M, et al. (2005) Defining and identifying crop landraces. *Plant Genetic Resources* 3(3): 373-384.

Von Neumann J and Morgenstern O (1944) *Theory of Games and Economic Behavior.* Princeton: Princeton University Press.

Von Uexküll J (1920) *Theoretische biologie.* Berlin: Paetel.

Wairegi LWI, Asten PJA, Giller KE, et al. (2016) *Banana–Coffee System Cropping Guide*. Nairobi: Africa Soil Health Consortium.

Waldman KB, Kerr JM and Isaacs KB (2014) Combining participatory crop trials and experimental auctions to estimate farmer preferences for improved common bean in Rwanda. *Food Policy* 46: 183–192.

Walker BA and Olson JC (1991) Means-end chains: connecting products with self. *Journal of Business Research* 22(2): 111–118.

Walker TS and Alwang J (2015) *Crop Improvement, Adoption and Impact of Improved Varieties in Food Crops in SubSaharan Africa.* Wallingford: CAB international.

Watkins L (2010) The cross-cultural appropriateness of survey-based value(s) research: A review of methodological issues and suggestion of alternative methodology. *International Marketing Review* 27(6): 694–716.

WHO (2009) *Global prevalence of vitamin A deficiency in populations at risk 1995–2005. WHO Global Database on Vitamin A Deficiency.* Geneva: World Health Organization.

Wierzbicka A (1984) Apples are not a "kind of fruit": The semantics of human categorization. *American Ethnologist* 11(2): 313–328.

Wigboldus S, Klerkx L, Leeuwis C, et al. (2016) Systemic perspectives on scaling agricultural innovations. A review. *Agronomy for Sustainable Development* 36(3): 1-20.

Yapa L (1993) What are improved seeds? An epistemology of the Green Revolution. *Economic Geography* 69(3): 254-273.

Yee E (2019) Abstraction and concepts: When, how, where, what and why? *Language, Cognition and Neuroscience* 34(10): 1257–1265.

Zimmermann EW (1933) *World resources and industries: A functional appraisal of the availability of agricultural and industrial resources.* New York: Harper & Brothers.

SUMMARY

Improving agricultural production in developing countries via increasing the availability of, access to, and use off improved seed can contribute to several global development goals set by the United Nations. Seed herein refers to 'true seed' in the botanical sense of the word, and any type of other propagate that can be used to reproduce plants. Improved seed refers to seed of improved varieties that are genetically enhanced, and seed of improved physical, physiological and sanitary quality. It is generally perceived within development programs that such improved seeds are developed and disseminated by the formal seed sector. Vegetatively propagated crops, such as banana, potato and cassava, are important staple crops in many developing countries. Smallholder farmers use of improved seed of vegetatively propagated crops is variable and often below experts expectation. Smallholder farmers mainly source their seed from informal seed sources, such as their own farm or fellow farmers.

To increase adoption rates of improved seed among smallholder farmers, seed system interventions are made. Those seed system interventions usually involve the strengthening of the formal seed system and encouragement of farmers' to source their seeds from formal seed sources. The CGIARs' Roots Tubers and Bananas (RTB) is one of the large scale research projects that aims to make available good-quality planting materials of a diverse set of high-yielding RTB varieties that are adapted to the needs and preferences of different stakeholders. As part of this program a toolbox was developed to study seed systems which includes research methods from several scientific disciplines such as agronomy, phytopathology, economics and marketing and consumer studies.

The overall objective of this thesis is to apply and evaluate different research methods from this toolbox that focus on farmers' seed-sourcing practices. A household survey, seed tracing study, focus group discussions, means-end chain analysis and experimental Vickrey auctions are applied to understand the different insights they provide in farmers' seed-sourcing practices (objective 1). The means-end chain analysis and experimental Vickrey auctions are relatively novel tools in the area of

seed-systems research. Via the underlying assumptions of these methods is explored how they can be improved and better adapted to understand farmers' seed-sourcing practices (objective 2). Furthermore is explored what aspects of farmers' seed-sourcing practices are captured or ignored by the different research methods, and how their combination can result in a more holistic understanding of farmers' seed-sourcing practices (objective 3). A final contribution is made exploring how research method do not only describe farmers' seed-sourcing practices, but also shape them by making certain aspects present while other aspects remain absent (objective 4).

In **chapter 2**, data collected with a large-N household survey is used to develop different cassava farmer typologies that can be used for the tailored design of cassava seed business models. Via a seed tracing study the cassava seed-sourcing practices of these different typologies are explored. We find that the majority of farmers of all typologies mainly use informal seed sources to acquire cassava stems. Because cassava can be multiplied while maintaining genetic characteristics farmers generally revolve to their own multiplication after a one-time acquisition of a new variety from a formal seed source. Therewith, cassava's characteristics complicate the development of commercial cassava seed businesses.

In **chapter 3** Focus Group Discussions and in-depth interviews are used to understand how farmers in Central Uganda manage banana diversity and select banana planting material. We find that bananas have important cultural meaning and are used for several end-uses. Those form major drivers for farmers to maintain a high diversity of (endemic) banana varieties. Farmers keep their banana plantations vital by increasing the lifespan of existing banana mats and planting new suckers or other types of propagates. This influences farmers' seed sourcing practices in several ways as it defines what varieties will be grown, how often new suckers or other propagated are required to replace an existing banana mat, and hence how many new suckers or other propagates farmers need.

In **chapter 4** the means-end chain analysis is applied to explore how Ugandan farmers evaluate, and why they value, different banana seed sources. We find that banana farmers in Uganda in general aim to fulfil similar goals with their banana production –

which are multiple and go beyond high yield and income – but that farmers perceive that different seed-souring practices will allow them to reach those goals. For example, some farmers perceive they can increase their available income by planting local varieties with long lifespans allowing them to save money on sourcing new suckers. Other farmers perceive they can increase their available income by growing improved varieties that give big bunches allowing them to sell them at higher market prices.

In **chapter 5** the results are shown of a qualitative follow-up study on experimental (Vickery) auction that aims to understand the monetary value that farmers place on different types of sweetpotato vines. Experimental auctions are relatively new methods in the area of seed-systems research. They can be used for different measurements such as understanding farmers preferences among different types of seeds, understanding farmers relative demand for different seeds, or to explore if a certain type of intervention would change farmers demand for different seeds. The objective of the auction we used as a follow-up was to find Rwandan farmers willingness-to-pay for different types of sweetpotato vines. The results of our qualitative follow-up study suggest that several assumptions that underly Vickery auctions might have been violated when applied in the context of smallholder farmers sourcing vegetative propagated planting material. To which extend the violation of assumptions is problematic depends on the specific objective of the auction, as experimental auctions can be used for several types of measurements.

In **chapter 6** several assumptions that underly the means-end chain analysis are explored. The means-end chain analysis originates from the field of marketing and consumer studies and is recently applied in seed-systems research as well. The means-end chain analysis is an umbrella term for several methodological parts that have been developed in a haphazard way in different research field. Therefore the means-end chain analysis lacks a clear theoretical underpinnings. We make several contributions to this methodological debate that regard attribute elicitation, coding of responses, and aggregation of responses. We find there is no ‘best way’ to apply the means-end chain analysis, and that the most suitable approach depends on the research question.

In the discussion of this thesis is explored what aspects of farmers' seed-sourcing practices are captured by the different research methods, and how they can be combined to get a more holistic understanding of seed systems. We find that quantitative research methods involving large sample sizes, such as surveys and experimental auctions, can shed light on diverse demand and find important correlations. Exploratory small-N case studies, such as Focus Group Discussions, in-depth interviews and the means-end chain analysis, can reveal subjective demand and explore causality and key drivers behind demand. Combining those methods can generate a more holistic understanding of farmers' seed souring strategy. The means-end chain analysis is the only method that systematically captures demand at different levels of abstraction. In some cases it might be easier for smallholder farmers to articulate a need at a higher level of abstraction (e.g. food security), than a specific demand at a lower level of abstraction that fulfills that need (e.g. quality seed), or vice versa. None of the applied research method seemed capable of capturing how demand emerges and evolves over time, nor whether demand captured in with the research method translates to substantive demand.

Research methods capture certain aspects of farmers' seed sourcing practices while other aspects are ignored. Via statements, descriptions or processes, research methods make certain aspects present while others remain absent. Therewith research methods are performative as they do not just describe seed systems, they contribute to shaping them. Seed quality is defined by the formal seed sector as a set of measurable characteristics on which seeds can be rated and scored. Via our research the relation between those characteristics and quality is made and remade. Focusing on by the formal sector defined quality characteristics ignores the local meaning of seed that compose quality according to farmers' perceptions. What is defined as quality seed shapes what seeds are made available by the formal sector now and in the future.

The binary divide between formal and informal seed systems is made and remade via scientific method. By adding new information and statements about seed systems, they are remade in slightly different ways. Surveys, seed network analysis, and experimental auctions focus on quantifiable relationships. They capture seed flows,

patterns, and transactions, but ignore the social norms and relations that guide such movement. If methods such as surveys gain hegemony on our research agenda, this means that the localized meanings or enactments of seeds and their exchange are repressed.

Framing adoption of improved seed as an individual decision-making problem shapes decision making. Research methods focus on finding the characteristics of famers who make 'the right decision' and try to identify the conditions under which they do so. The focus on the individual means that interventions and agricultural extension services are geared towards changing the individual, instead of changing products (e.g. seeds), economies (e.g. seed exchange mechanisms), and policies (e.g. seed laws) to suit communities.

To establish and develop a formal seed sector that distributes seed via market principles requires a change of social relations between farmers, and between farmers and their seeds. Our research methods contribute to the 'remaking' of those relations. They make seed quality observable and calculable, track and quantify seed exchanges and flows, identify the characteristics of those who make decisions 'as they should' and the conditions under which they do so, and provide farmers' value for seed expressed in prices. What we might ignore when quantifying seeds and seed systems to enable their marketization are the relations between culture and agriculture, such as the diverse cultural end-uses that are key drivers behind the preservation of banana varieties in Central Uganda. Disentangling such relations means that certain realities get lost.

Recognizing the performative nature of methods stimulates us to focus on what works instead of what is true or wrong. This opens up the possibility of multiplicity as solutions can be diverse. Using diverse research methods form different disciplines is a first step towards a more holistic understanding of smallholder famers' seed-sourcing strategies. Understanding what it is those methods actually do, and considering whether this is desirable, is a second step.

APPENDICES

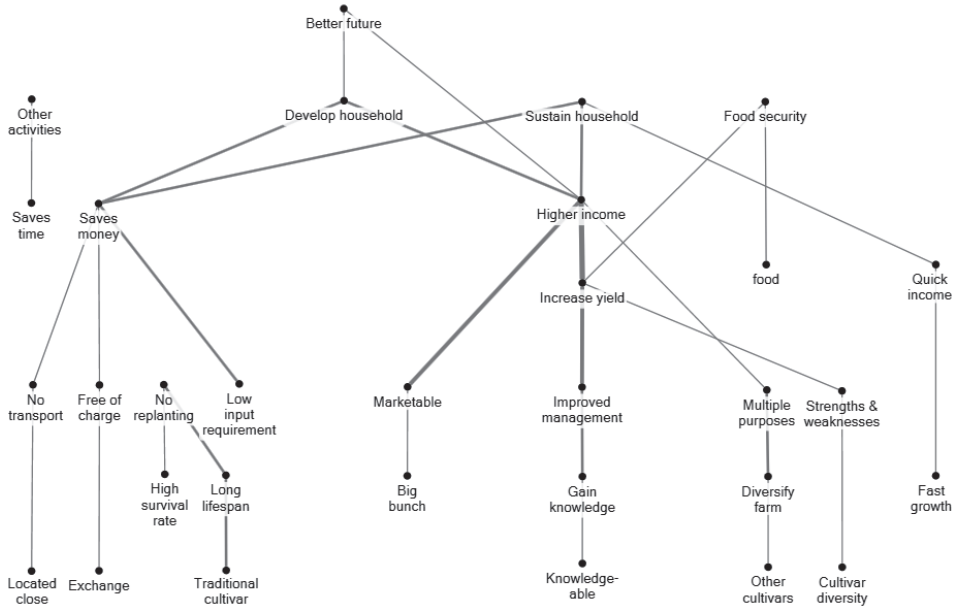
Appendix 1

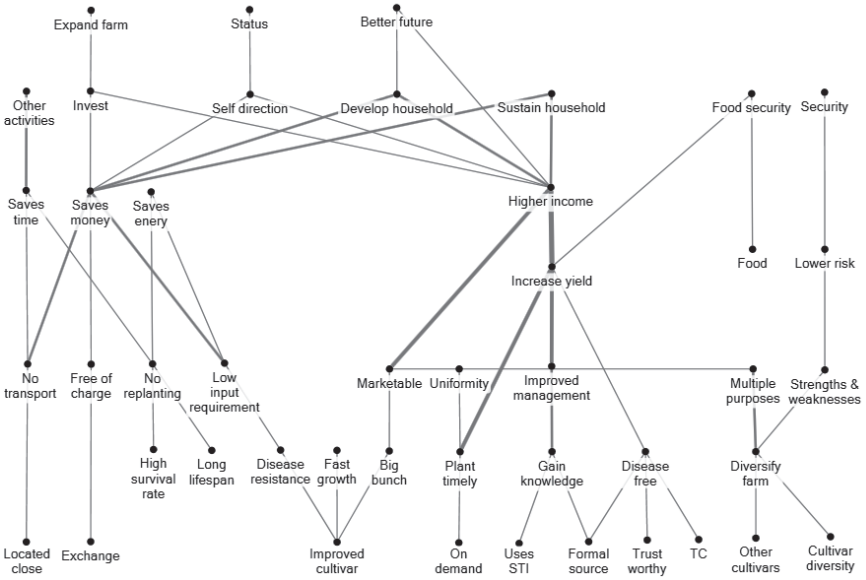
Appendix 1. Varieties identified as grown by farmers, their year of official release in Rwanda (approximate), and the percentage of farmers growing them (n=390).

No.	Variety name(s)	Type	Grown by	Year official release
1	NASE14, Tubura, Umweru, Imyeru, Bizigira, RAB	Improved (NASE 14)	51%	2018
2	Macadamia	Improved (MM96/8299)	44%	2021
3	RAB	Improved varieties	3%	2018
4	NAROCAS1	Improved (TZ130)	1%	2018
5	Kizere	Improved (I92/0057)	8%	2006
6	Nyiragatare, Mbakungahaze	Improved (95/NA/00063)	4%	2006
7	Mavoka, Mavuta Umuhondo	Improved (MM96/0287)	4%	2009
8	Mbagarumbise	Improved (MH95/0414)	1%	2006
9	Serura, Seruruseke	Improved (MM96/5280)	1%	2009
10	Ndamirabana	Improved (TME 14)	<1%	2006
11	Eala 07, Gapfunsi, Gitaminsi	Eala 07	15%	1975
12	Creolinha, Gafuni, Rushyirwinkuba, Rutanihisha, Zanagafuni	Creolinha	8%	1985
13	Amuri, Amurine, Mure	MM96/9688	6%	trial
14	Maguruyinkware, Buguru, Bwinkware	Maguruyinkware	3%	1985
15	Kibombwe Buryohe, maryohe, Iminayelo, Kibomwe, Iminayiro	Kibombwe	2%	1985
16	Bukarasa	Bukarasa	1%	1985
17	Nyirakarasi		8%	
18	Gahene		6%	
19	Nyabushabure		3%	
20	Kigoma		2%	
21	Gacyacyali		2%	
22	Imiribwa		2%	
23	Rwakarori		2%	
24	Nyiramasibo		2%	
25	Imizungu		1%	
26	Imicyari		1%	
27	Itukura		1%	
28	Kavumu		1%	
29	Kicaro		1%	
30	Amaso manini		<1%	
31	Charlotti		<1%	
32	Cyiso		<1%	
33	Iminyarwanda		<1%	
34	Imitanzaniya		<1%	
35	Makesa		<1%	
36	Manoyinanga		<1%	
37	Mbundanyi		<1%	

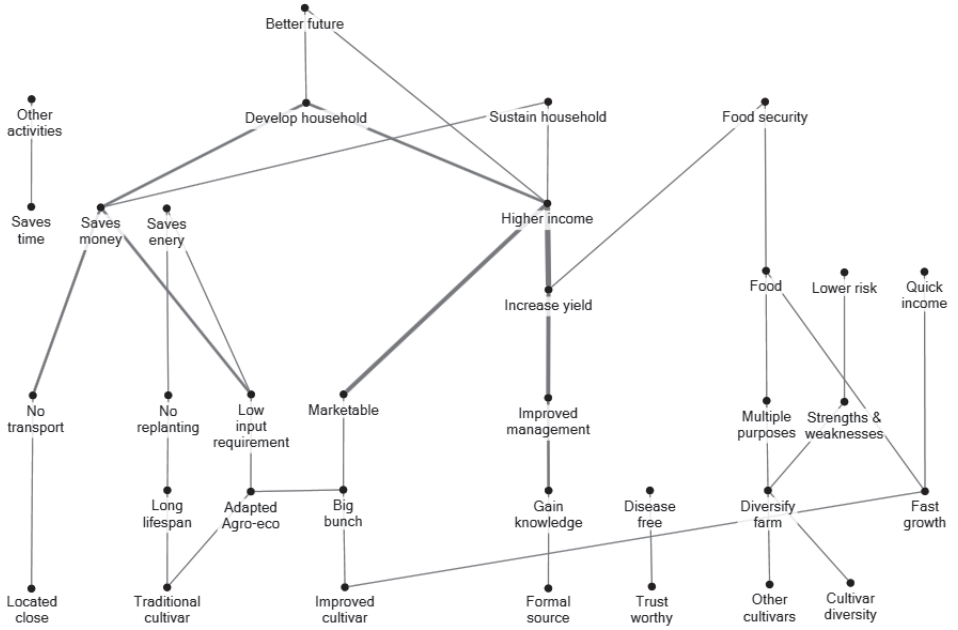
38	Mushedire		<1%	
39	Nyiramabuye		<1%	
40	Sinihaniza		<1%	
41	Umugande		<1%	
42	Umunanira		<1%	
43	Butukura		<1%	
44	Makungahaze		<1%	
45	Umubombwe		<1%	
46	Pakiya		<1%	
47	Rutare		<1%	

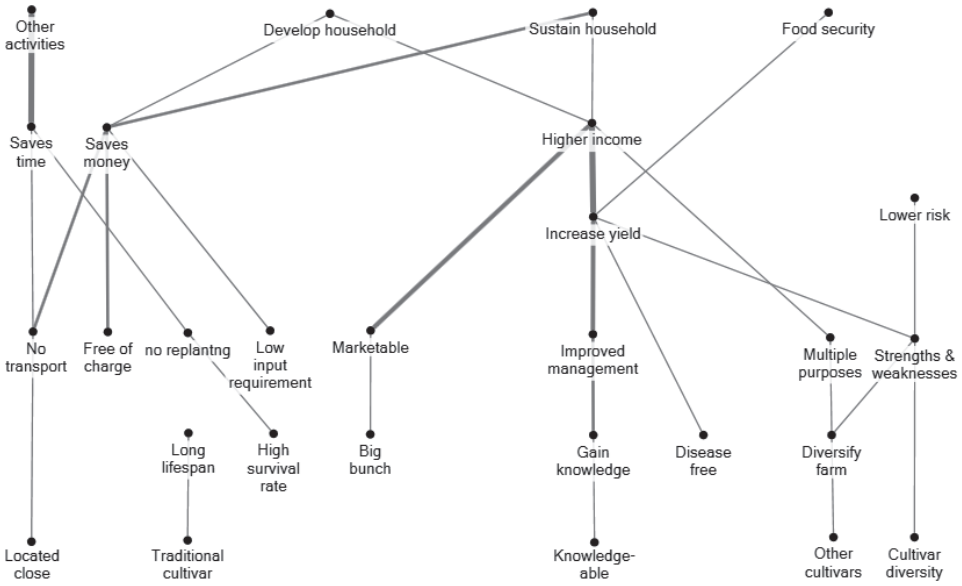
Appendix 2





ANNEX 2. Hierarchical value map based on the number of respondents making a link between constructs of a) small-scale farmers (cutoff level n = 4; n = 20) and b) large-scale farmers (cutoff level n = 2; n = 11).





ANNEX 3. Hierarchical value map based on the number of respondents making a link between constructs of a) men (n = 17; cutoff level n = 3) and b) women (n =14; cutoff level n = 3).

Appendix 3

Appendix 3. Contrasting word-pairs elicited during the repertory grid (n=18), and the number of farmers preferring them (Preferred n). Farmers ranked the importance the attributes in each word-pair on a scale of 1 to 10 (Ranking). Attributes in a dark shade where the attributes promoted during the auctions.

Attribute	Preferred n	Attribute	Preferred n	Ranking min	Ranking max	Ranking mean
Source DVM	16	Source farmer	0	5	10	8.6
Improved variety	14	Local variety	0	6	10	8.6
Vitamin A	13	No vitamin A	0	7	10	8.8
High yielding	8	Low yielding	0	6	10	8.6
Disease free	6	Diseased	0	7	10	8.5
Big leaves	4	Small leaves	1	8	10	8.8
Light stem	4	Dark stem	1	7	10	8.2
Early maturity	5	Late maturity	0	9	10	9.6
Cash required	2	No cash required	2	5	10	8.2
Vegetable	5	No vegetable	0	7	10	8.6
Long vines	3	Short vines	1	3	10	7.5
Thick stem	4	Thin stem	0	6	9	7.0
Short internodes	2	Long internodes	2	8	9	8.8
Takes care	4	Does not take care	0	8	10	9.0
Hand leaves	3	Round leaves	0	4	6	4.7
Red roots	2	White roots	0	8	9	8.5
Red leaf tips	2	Green leaf tips	0	7	10	8.5
Easy multiplied	2	Not easy multiplied	0	8	10	9.0
Good leaves	2	Bad leaves	0	10	10	10.0
Good taste	2	Bad taste	0	9	10	9.5
Adapted to soil	2	Not adapted to soil	0	9	10	9.5
Many side stems	1	Few side stems	0	7	8	7.5
No flowers	1	Flowers	0	10	10	10.0
Soft stem	1	Hard stem	0	6	6	6.0
Make Mandazi	1	Not make Mandazi	0	8	8	8.0
Easy accessible	1	Not easy accessible	0	5	5	5.0
Dark leaves	1	Light leaves	0	6	6	6.0
Easy to cook	1	Not easy to cook	0	7	7	7.0
Research	1	No research	0	8	8	8.0
Deep roots	1	Shallow roots	0	5	5	5.0
Grew in good soil	1	Grew in bad soil	0	4	4	4.0
Few generations	1	Many generations	0	10	10	10.0

ACKNOWLEDGEMENTS

Writing these acknowledgements feels like the final words about a very interesting journey into the unknown. Considering that my education started at the lowest (these days we say most practical) level, and that I have gone through every educational level in the Netherlands since, it actually was a very long and quite unconventional trajectory. I hope my story will be an inspiration for students to follow their dreams no matter where they start from, but also for those who are in the position to support students and can provide opportunities. Throughout my life there have been people who supported and encouraged me to take a next step, and who gave me opportunities. I thank all those people and without them it would not have been possible to produce this PhD thesis.

Two of those people who require a special thanks are Conny Almekinders and Ynte van Dam. Both saw the potential in me to continue with a PhD and that you allowed me the freedom to explore different directions and new ideas. It has been an absolute pleasure to work with you and I learned a lot from our discussions. Not only regarding scientific content, but also about writing, publishing, functioning within a project and dealing with life in general. I also want to thank my promotor Cees Leeuwis for his guidance especially in the final phases of writing my thesis. Your contributions and ideas on how to make the thesis a coherent story were very valuable. For all three of you: I hope finalizing this PhD is not the end of our collaboration, but rather the beginning of new and interesting research collaboration.

It feels like a privilege to have been part of the RTB family. The RTB group has always been very open for the contributions and suggestions of the 'RTB beginner team': Isra, Elly, Kwame, Erik, Lucy, Ricardo and Kelsey. This allowed us to grow, experience and learn. I am very happy I got to meet all of you, and I already miss our annual meetings! I hope we will all stay in touch and that we can continue working together in new projects.

I also want to thank all the colleagues from different CGIAR institutes; Bioversity Uganda, CIP Nairobi and Kigali, and IITA Kigali, I have worked with over the years. Several of you are co-authors in the chapters of this thesis. Anne, Jeroen, Pricilla, Sam, Rhys, Marc, Silver, Athanase, Silvie and Marthe, I have learned a lot from our collaboration! Furthermore I will never forget the numerous field visits where something exiting always happened. It was a pleasure to talk to so many farmers in Eastern Africa and listen to their interesting stories. I am grateful they were willing to share their information with me on which this thesis is largely based. Without them my research would not have been possible.

I want to say thanks to the whole KTI group, and to the admin group of which I have been a member myself for a short while. Inge, Germaine, Cathelijne, Bea, Vera, Mirjam, Meta and Jennifer, thank you for all the support and the fun coffee breaks we have had.

Finally I want to thank my family and friends for their support and trying to understand what I have actually been doing during those 'holidays'. I can imagine it must have been stressful at times when I was traveling to an unknown country far away. Nevertheless you have always encouraged me to follow my dreams. Your names are many and I am sure I will forget more than one if I tried to write them all down.

ABOUT THE AUTHOR

Fleur Kilwinger was born Oosterhout Noord-Brabant in 1991. She went to primary school in her hometown Dussen. Being passionate about animals and nature at a young age, she went to the 'Lagere Agrarische School' in Andel for her VMBO diploma. Thereafter she went for her MBO diploma at the 'Middelbare Agrarische School' in Breda where she studied to become a florist like her grandma. Despite finishing this program it turned out this was not her passion. Not sure what to do now, she decided to start a bachelor applied biology at the 'Hogere Agrarische School' in 's-Hertogenbosch. Although being very interested in animal sciences and ecology as well, she specialized herself in plant sciences. During an internship at a large farm in Mozambique her interest in social aspects of plant sciences was sparked, and if a bachelor degree was possible, then why not getting a master degree as well?

She started her MSc plant sciences at Wageningen University and for an introduction into social sciences related to agriculture she ended up in the class of Conny Almekinders. Being inspired by the course, she ended up doing an MSc thesis study on banana diversity and uses in Uganda. After she graduated in 2017, she continued her collaboration with Conny in the CGIAR's Roots Tubers and Bananas (RTB) program. Because they needed expertise on consumer and marketing studies, to further study farmers' demand for seed, Ynte van Dam joined the team. This research ultimately turned into a PhD thesis.

Fleur Barendina Maria Kilwinger
Wageningen School of Social Sciences (WASS)
Completed Training and Supervision Plan

Name of the learning activity	Department/Institute	Year	ECTS*
A) Project related competences			
A1 Managing a research project			
WASS Introduction Course	WASS	2022	1.0
Writing research proposal	WUR	2020	6.0
Peer review of 3 scientific manuscripts	WUR	2019-2022	1.0
Participation and presenting at RTB annual workshops	CGIAR - RTB	2017-2021	2.0
A2 Integrating research in the corresponding discipline			
Research methodology: From topic to proposal	WASS	2020	4.0
Behavioural economics, UEC 51306	WUR	2020	4.0
PE&RC summer school on seed systems and participatory plant breeding	PERC	2020	2.0
Training session on the RTB toolbox	RTB	2021	2.0
B) General research related competences			
B1 Placing research in a broader scientific context			
Critical perspectives on social theory	WASS	2020	4.0
Course on means-end chain analysis	WUR_MCB	2017	3.0
B2 Placing research in a societal context			
Organizing partner and stakeholder workshops for the CASS project	NWO - CASS	2019-2021	1.8
Writing blogs	CGIAR - RTB	2018-2021	0.2
Development of 4 RTB tool user guides	CGIAR - RTB	2019-2021	2.0
C) Career related competences/personal development			
C1 Employing transferable skills in different domains/careers			
Supervision ACT team	WUR	2019	1.0
RTB workshop proceedings	CGIAR - RTB	2018-2020	1.0
Development of an Excel-based tool for means-end chain analysis	CGIAR - RTB	2021	4.0
Total			**38.0**

*One credit according to ECTS is on average equivalent to 28 hours of study load

FUNDING

The research described in this thesis was financially supported by the CGIAR Research Program on Roots, Tubers and Bananas (RTB) and supported by CGIAR Trust Fund contributors https://www.cgiar.org/funders/. Funding support for this work was also provided by the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO) through the NL-CGIAR research program. Financial support from Wageningen University for printing this thesis is gratefully acknowledged.

Printed by ProefschriftMaken.nl