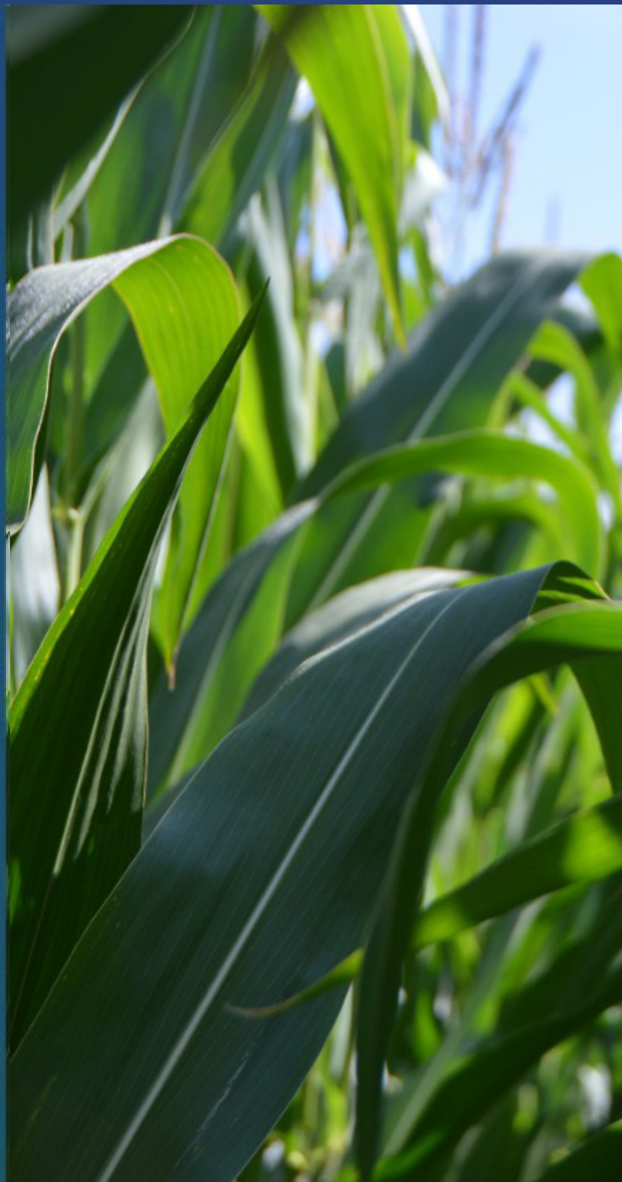
Learning, Agricultural Technologies and Rural Livelihoods in Uganda

Claris Riungu

Propositions

1. Without proper stimulation of interactions among actors involved in agricultural information dissemination programs, learning and technology diffusion among farmers would remain unattainable.
   (this thesis)
2. In rural Uganda, the farm and the nonfarm economy are so integrated at the household level that policies targeting only one of the two are bound to fail.
   (this thesis)
3. Advancement of interdisciplinary research is hindered by high-impact journals favouring mono-discipline research.
4. Analysis of complex technological change is hampered by the reductionist approach employed in most scientific studies about technology adoption.
5. Current efforts in achieving gender equality is akin to using a body wrap to lose weight.
6. Social media is a technology and therefore advantages, as intended by designers, can become disadvantages in particular user contexts.
7. Unlearning is important for a successful PhD trajectory.

Propositions belonging to the thesis, entitled

Learning, Agricultural Technologies and Rural Livelihoods in Uganda

Claris Riungu
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Learning, Agricultural Technologies and Rural Livelihoods in Uganda

Claris Riungu

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Learning, Agricultural Technologies and Rural Livelihoods in Uganda

Claris Riungu

Thesis

submitted in fulfilment of the requirements for the degree of doctor

at Wageningen University

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Prof. Dr A.P.J. Mol,

in the presence of the

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To my family

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Chapter 1

General Introduction

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General Introduction

1.1 Background

The agricultural sector in Sub-Saharan Africa (SSA) is dominated by smallholder households that have limited access to markets and rural infrastructures and are vulnerable to shocks. Reliance on rain-fed agriculture and little use of improved technologies makes them susceptible to declining production (GoU, 2015; Nyasimi et al., 2016). Technology diffusion and adoption is key in the growth of the agricultural sector because they increase productivity, income and food security (Foster & Rosenzweig, 2010). It is against this backdrop that donor-funded agencies support a green revolution for Africa – breeding, production and dissemination of improved agricultural technologies and improved management practices (Mabaya et al., 2018 (Revised 2019)).

The development and dissemination of new technologies may be affected by several factors. First, political and economic environments, contrasting seed system politics, conflicts of interests among stakeholders, and commercial sector interests affect policies around improved technologies (Scoones & Thompson, 2011). Second, demand for new technologies will be low if local agro-ecological and sociocultural diversity are not considered (Brooks, 2014). Third, farmers are viewed as passive participants when new technologies are developed and disseminated, and their experience is not acknowledged when dealing with the complexity of local agro-ecologies. This adversely affects the process of adoption (Schurman, 2018). Lastly, improved technologies alone are not enough to drive a green revolution but need to be supported by institutions such as input and product markets and effective extension systems that bring the new technologies and knowledge to the farmers.

A large and growing body of research is dedicated to find effective technologies and efficient ways to disseminate information, and to quantify the economic effects of agricultural innovations (Duflo et al., 2008, 2011). However, there is little research into how innovation projects are implemented, and the interactions between the actors involved in this process (and the associated implications for project outcomes). Yet the nature of these complex processes and interactions is likely to affect the dissemination of information, and the process of learning and actual adoption of new technologies.

Farmer learning is key to create understanding of the potential costs and benefits of improved technologies. According to Stone (2016), learning can take place in three ways: social learning, environmental learning and didactic learning. Social learning involves joint learning and information exchange between farmers (Stone, 2007). Environmental learning involves learning by experimenting with the technologies to observe the performance and payoff. Didactic learning is learning whereby external agents such as governments, companies, and non-governmental organisations transfer knowledge to farmers (Stone, 2016). Most studies on learning mainly focus on the effect of a specific intervention on the target outcome (Bandiera & Rasul, 2006; BenYishay & Mobarak, 2019; Stone, 2016). However, the learning process shapes the outcome. Therefore, it is important to know more about the learning process, how different forms of learning can be integrated, and how the learning process affects the awareness about, and adoption, of promoted technologies. Understanding the learning process, the constraints to learning and how these affect technology diffusion, adoption and outcomes is challenging and requires careful analysis.

Due to the intricacies of learning, adoption is not a linear process. However, it is accompanied by complex dynamic changes. For example, a farmer may try out a technology and revert to an older one or give it up if the expected benefits are not realised, or the cost of implementing is too high. The farmer may also decide not to completely abandon the older technology but to adopt the new technology alongside the older one. The decision to use, the scale of use, and the decision to abandon an improved technology will depend on the costs and benefits within the context of a specific farmer, which may differ greatly between farmers even on a small scale (Magnan et al., 2015; Suri, 2011). Assessing the impact of the technology will help us to assess whether the use of an improved technology is profitable.

Despite the importance of agriculture for the livelihoods of smallholder farmers in Sub-Saharan Africa, it is far from their sole source of income. Many farmers combine farm activities with non-farm activities (Jiao et al., 2017; Liu & Lan, 2015). They allocate their resources (e.g. land and labour) not only to farm production but also to non-farm employment or businesses to be able to survive or to improve their living standards (Ellis, 1998). Rural livelihood strategies are often complex, and farm and non-farm activities may be intertwined through production, consumption, and investment. Intersectoral linkages are especially strong in Sub-Saharan Africa (Deichmann et al., 2008). For example, non-farm and farm activities complement each other by injecting funds earned in one activity into the other, i.e. a household can use savings from non-farm activities to purchase inputs or adopt an improved agricultural technology, or they can use savings from farm activities to start a business. In addition, time spent in off-farm activities is not available for the farm activities and vice versa. Understanding rural livelihood strategies will help development agencies and policymakers develop appropriate policies to support smallholders (Tittonell, 2014).

This thesis was written in the context of the 3ie TW4/1010 project led by Tegemeo Institute of Agricultural Policy and Development, Egerton University, Kenya. Based on survey data and qualitative data from smallholder farmers in eastern and mid-western Uganda, the thesis gives insights in two main issues: First, it analyses the implementation process of a specific technology dissemination effort that failed to achieve adoption. The findings will inform future programme design and implementation. Second, it provides insights in the dynamic adoption and livelihood strategies of smallholders and their effect on incomes to support developing and implementing impactful policies.

1.2 Problem statement

Adoption of improved agricultural technologies has been extensively studied (Conley & Udry, 2010; Duflo et al., 2008, 2011; Shikuku et al., 2019; Tjernström, 2017). Low adoption of agricultural technologies has been linked to information constraints (Foster & Rosenzweig, 1995). It is envisioned that information dissemination will lead to knowledge diffusion and adoption of improved agricultural technologies. Adoption of agricultural technologies should lead to increased yields, which will boost farmers' income through increased sales of surplus crop output. To encourage the adoption of agricultural technologies, governments and development agencies have made large investments in extension and information interventions. However, there are many cases where these interventions have failed to provide the desired results (Ashraf et al., 2013).

Social and environmental learning have largely been promoted in agriculture (Bandiera & Rasul, 2006; Kondylis et al., 2017; Stone, 2007, 2016). However, the understanding of various social actors and learning dynamics is limited. The assumption that the information flow is flawless and that farmers' beliefs are automatically updated through learning has been challenged. As stated earlier, learning consists of three types of interactions: social, environmental, and didactic. The ways in which these interactions take place could have an impact on the diffusion of technology (Stone, 2016). There is evidence that providing training to contact farmers (in our case demo hosts) had little effect on villagers' knowledge and technology diffusion (Kondylis et al., 2017).[1] There is still little or no evidence about how different interactions between farmers and information/technology disseminators affect learning and technology adoption.

Adoption can either be complete or partial; reasons for allocating a portion of land to improved technology include: to experiment (Foster & Rosenzweig, 1995), profitability (Suri, 2011), biotic stresses and inaccessibility of markets (Simtowe & Mausch, 2019) and labour scarcity (Moser & Barrett, 2006). Building upon these studies, most research has focused on adoption, with little attention being paid to disadoption. Exceptions include: (Moser & Barrett, 2003, 2006; Sanou et al., 2017; Simtowe & Mausch, 2019; Wakeyo & Gardebroek, 2015). Disadoption of improved varieties is also relevant for the study area, but the extent of disadoption of improved maize varieties among maize farmers in Uganda is not fully understood. It would be interesting to extend the research to study processes of disadoption of improved maize varieties, and learn about disadoption trends, factors, and reasons for adoption and disadoption in Uganda.

Other studies have focused not only on the determinants of adopting improved technologies, but also on their impact (Khonje et al., 2015; Manda et al., 2018; Mason & Smale, 2013; Mathenge et al., 2014). Assessing the impact of adopted agricultural technologies is challenging because attributing impacts to uptake of a specific technology is difficult (e.g. due to confounding selection effects). Changes in outcome indicators such as household income may not be directly attributed to the agricultural technology. Maize yield and maize income per hectare are better indicators for estimating direct impact. In Uganda, (Nabasirye et al., 2012; Okoboi, 2010; Simtowe et al., 2019; Sserunkuuma, 2003)

[1] In addition, a subsample of the farmers indicated that they believed the bean seed was not suitable for them, given agro-ecological and market conditions.

investigated the adoption and impact of improved maize varieties. The downside of these studies is that they used cross-sectional data which do not consider time-invariant farm and household differences. To fully account for this shortcoming, we use panel data and fixed effects with the inverse probability weighting (IPW) estimator to adjust for unobserved individual and farm differences as well as time invariance.

Diverse livelihood strategies provide more options to the rural poor to improve incomes in Sub-Saharan Africa. Households allocate their resources to various activities to improve their livelihoods or provide a cushion against any setbacks. Furthermore, it has been indicated that off-farm incomes boost households' incomes (Barrett, Reardon, et al., 2001). Factors influencing the choice of livelihood are livelihood assets, location, and distance to key facilities (such as road, market) (Jansen et al., 2006; Van den Berg, 2010). The question of livelihood diversification in rural Uganda has been investigated (Ellis & Bahiigwa, 2003; Smith et al., 2001; Wichern et al., 2017). However, the livelihood strategies, transitions from one livelihood strategy to another, and changes in incomes have rarely been studied. In order to establish effective policies, it is essential to unravel the livelihood strategies transition and outcomes as well as factors that hinder households from engaging in strategies.

1.3 Research objective and questions

The overarching objective of the thesis is two-fold. The first is to understand the interrelationship between the learning process and adoption of improved technologies and the impact of adoption on productivity and income. The second is to promote understanding of livelihood strategies, their dynamics and outcomes of each strategy among rural households in eastern and mid-western Uganda.

The specific research questions are:

1. How does learning take place among farmers, and how do the involved actors (agro-dealers, demo hosts, farmers, extension staff) interact in the dissemination of information and improved seeds? (Chapter 2)
2. What are the dynamics of technology adoption, and what are the determinants and motivations for adoption/disadoption decisions? (Chapter 3)

3. What are the effects of the use of improved maize seed on productivity and income? (Chapter 4)
4. What are the livelihood strategies, their dynamics and their outcomes among rural households in Uganda? (Chapter 5)

1.4 Local context

In Uganda, the majority of the farmers cultivate small plots, growing a variety of crops for food and income (Mango et al., 2018). To diversify their income, they engage in off-farm employment, e.g. business and casual employment. The commonly grown crops are maize, beans, cassava, sweet potatoes and groundnuts. They retain part of their production for consumption (Ellis & Freeman, 2004). Smallholder agriculture is faced with uncertainty, risks and challenges, which forces households to consider diversifying or opt for other sources of income. Factors such as low productivity, limited commercialisation, limited use of improved technologies, high cost of inputs, limited market access, and poor rural infrastructure combine to limit agricultural profitability and incomes. Many smallholder farmers live below the poverty line or even in extreme poverty (Anderson et al., 2016). Therefore, the government has promoted a shift from subsistence to commercial agriculture through the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF). The priority crops considered for commercialisation include maize, beans, rice, sorghum, finger millet, bananas and coffee, and fruit trees such as oranges and apples.

Several institutions work together or independently to support breeding, multiplication, information dissemination and access to improved varieties to raise households’ productivity and incomes. In Uganda, the Alliance for a Green Revolution in Africa (AGRA) works together with other stakeholders, e.g. MAAIF, the National Agricultural Research Institute (NARO), the National Seed Certification Service (NSCS), agro-dealers and seed companies in facilitating the release of new varieties, quality control, and production and distribution of the certified seed varieties. Depending on the availability of technical and financial support, some crops are given priority over others. Between 2000-2017, more maize varieties were released than bean, millet, and sorghum combined, and more improved varieties are released for maize than for any other crop (Mabaya et al., 2016), possibly because maize is considered both as a cash crop and a subsistence crop. Between 2013-2015, nineteen maize varieties and three bean varieties were released (Mabaya et al., 2016). Between 2015-2017, 26 maize varieties, five bean and millet varieties, and four sorghum varieties were released (Mabaya et al., 2018 (Revised 2019)). Hybrids and open-pollinated varieties (OPVs) are the common improved varieties used in maize production. OPVs are the most popular maize varieties based on their early maturity and recyclability (Mabaya et al., 2018 (Revised 2019); Mastenbroek & Ntare, 2016).

Research institutes and other partners create awareness of the improved technologies to farmers through farmer field schools, demonstration fields, field days and mass media. In addition, the Government of Uganda launched Operation Wealth Creation (OWC) in 2013 to provide extension services and distribute the improved seeds to rural farmers. However, these extension programmes have reached only a limited number of farmers due to an unreliable support system and unequal distribution of technologies (Nakazi et al., 2017). This results in low adoption of new and improved technologies such as seeds (MAAIF, 2014), and low and stagnating production and incomes.

Demonstration plots are used to introduce new technologies to farmers (Kondylis & Mueller, 2013; Kondylis et al., 2017). In some cases, field days are conducted at the demonstration site to further train farmers in the new technology. For demonstration plots to be effective, the process of dissemination and information delivery must be smooth. This is dependent on the interactions among the actors involved (farmers, hosting farmers/demo hosts, agro-dealers, extension staff), the delivery of information, farmers' preferences regarding the new technology, the affordability and accessibility of the technology, and its perceived costs and benefits. Findings about the effects of demonstration plots in promoting technology use are mixed, e.g. a study found that demonstration plots were more effective among women compared to the larger community (Kondylis & Mueller, 2012).

1.5 Theory

1.5.1 Information and learning about new technologies

Lack of information about new technologies is a major factor hindering adoption (Foster & Rosenzweig, 1995). When a new variety is introduced to the market, it is necessary to promote and distribute it to the targeted population (farmers). Studies have focused more on social learning than on environmental learning in behaviour change. In agriculture, social learning is important, but it may not work well with weak environmental learning because the different types of learning reinforce each other. In the absence of environmental learning, farmers tend to conform to what is popular (Stone et al., 2014). Impediments to environmental learning include: inconsistency of the effects of the technology (Tripp, 2001a), unrecognizability (Tripp, 2001b) and introduction of technologies at short intervals (Stone et al., 2014).

Didactic learning – the process by which third parties such as agro-dealers and input sellers are providing information and instructions about new technology to farmers – is also important. While many studies have evaluated learning processes, the often important role of didactics in the learning process is frequently ignored (Stone, 2016). Didactic, environmental and social learning should integrate to make a technology sufficiently attractive to farmers to induce its use. Interaction among farmers and other actors such as demo hosts, commercial agents, and researchers, is crucially important in information dissemination and learning.

How the learning process played out for a specific information dissemination and seed distribution project in Uganda is elaborated in chapter 2 of the thesis. In this project, demonstration plots alongside field days were used to disseminate information to promote the uptake of new maize and bean varieties. Demo hosts, seed company, agro-dealers and researchers provided information about new maize and bean seeds, and improved management practices.

1.5.2 Adoption of improved technologies

Despite their potential to increase yields and income, the adoption of improved technologies is low in SSA (Pamuk et al., 2014). Numerous studies have identified reasons for low adoption, e.g. (Bold et al., 2017; Magnan et al., 2015; Munshi, 2004; Stone et al., 2014; Tjernström, 2017). However, much less attention has been paid to the equally important high rates of disadoption and the dynamics that induce farmers to revert to older technologies (Gedikoglu & McCann, 2009; Wakeyo & Gardebroek, 2015).

Each household is unique, with its own motivations and constraints in the adoption process as for example described in the non-separable farm household model (Taylor & Adelman, 2003). Agricultural households are both producers and consumers. Hence, they make joint decisions for production and consumption. To maximize utility, activities are allocated subject to constraints such as land, labour and the technology itself. The households choose the activity that yields the highest utility after comparing the available activities. Awareness and knowledge of the technology, accessibility and affordability of the technology, and the technology's contribution to the objective of the household contributes to the technology adoption decision making. Moreover, there are other changes that go hand in hand with technology adoption (Leeuwis, 2013). These changes include crop husbandry management and social arrangements. Farmer and household characteristics such as age, education, gender and composition of the households contribute to technology adoption.

The households may opt to stop using the technology either temporarily or permanently. This study poses that for a household to disadopt, he must have adopted in the previous season(s). Accordingly, a household that adopted improved technology in previous season is classified as a disadopter if s/he does not adopt the technology in the next season. Labour requirements, farm size, availability of family labour, and household preferences influence discontinued use of technologies (Grabowski et al., 2016; Marenya & Barrett, 2007; Moser & Barrett, 2006; Wendland & Sills, 2008). Environmental factors, technology specific factors, limited accessibility of the technology and lack of finance for acquiring the technology may hinder the adoption and continued use of a technology. Poor rural financial markets affect liquidity and may hamper purchase of the technology. Additionally, consumption preferences play an important role in shaping the use of technologies, e.g. farmers prefer local maize varieties for preparing their meals in Western Kenya (Mango & Hebinck, 2004).

Decision making about the use of improved technologies and the emerging adoption dynamics of the improved maize varieties are addressed in chapter 3. The focus is on certified maize seeds. Although such seeds generally have higher yields and germination rates, they may vary in other traits such as shorter maturity period, drought tolerance, disease/pest resistance, and improved nutritional value. The use of certified seeds involves higher production costs due to relatively high costs of seeds and associated technologies such as additional weeding. Lack of resources may thus result in some farmers discontinuing use of the improved varieties, either permanently or temporarily. Considering that adoption is only attractive if the costs outweigh the benefits, chapter 4 addresses the impact of certified maize seed on yields and income.

1.5.3 Livelihood strategies and dynamics among rural smallholder households

Increased population pressure, shrinking farm sizes, erratic weather conditions, and pests and diseases negatively affect agricultural productivity and incomes. These shocks can be countered by using improved varieties which are drought- or pest-resistant, or take a shorter time to mature (Niang et al., 2014; Phiri & Saka, 2008). However, not all farmers use them, and they may decide to look for ways to diversify and complement their income sources. Diversification helps households meet their consumption needs (Waha et al., 2018) and combined crop and livestock farming is commonly practised to increase farm income (Di Falco et al., 2011; Thornton & Herrero, 2015). Crop diversification is another way that farmers try to meet their consumption needs (Makate et al., 2016; Mango et al., 2018). But they also diversify by engaging in off-farm activities. Off-farm income contributes to about 35% of household income for smallholders in SSA (Haggblade et al., 2010). The combination of activities that households engage in is called their livelihood strategy. Livelihood strategies are dynamic and may change depending on the farmers' situation (Barrett et al., 2005; Ellis, 2000). However, even though livelihood strategies have been studied broadly in different countries, little is known about their dynamics among rural households, especially in rural Uganda. Chapter 5 addresses this question by examining the livelihood strategies, the determinants of choosing a strategy, the dynamics of livelihood strategies, and the livelihood outcomes of each livelihood strategy.

This thesis advances our understanding of mechanisms of social, environmental and didactic learning, and their influence on technology awareness, knowledge and adoption. Whereas social learning affects technology use, little research has been done on environmental and didactic learning. Optimal technology adoption could also be affected by interaction between different actors; hence this is also assessed. There is also scant empirical evidence about the adoption and dis-adoption dynamics of technologies, and implications for livelihood strategies dynamics in Uganda. This thesis aims to contribute to this topic.

1.6 Research methodology

1.6.1 Overview of research methods

The research draws evidence from primary data collected in four districts, namely Tororo and Iganga districts in Eastern Uganda, and Masindi and Hoima districts in the mid-western region of Uganda. Data were gathered using both quantitative and qualitative approaches as discussed in this chapter.

In economics, qualitative research methods are sparingly used due to concerns about unrepresentativeness and subjectivity in comparison to quantitative research, which, if executed well, is considered to be rigorous, robust, objective, and representative. However, both methods have their strengths and can provide scientifically valuable knowledge (Starr, 2014). The use of different methods with complementary strengths and perspectives enhances the breadth and depth of results (Akimowicz et al., 2018; Greene, 2007; Hesse-Biber & Johnson, 2015; Johnson et al., 2007). In this thesis, we used the sequential mixed method where quantitative data collection was followed up by qualitative methods to explore emerging themes with fewer individuals (Creswell, 2009).

The quantitative research method is mostly used to investigate relationships between phenomena and causal effects. Advantages of quantitative research are: (i) the sample size is large enough to make inferences from; (ii) the researcher can deal with measurement errors, missing data, and self-selection (Helper, 2000); (iii) it is relatively easy to replicate; (iv) quantitative research is generally deductive; (v) use of models and algorithms increases accuracy of a phenomenon and predicting future trends; (vi) it is easier to collect data faster; (vii) it is relatively easy to analyse. Causal relationships between concepts and variables can be explored and generalisation of results is possible to some extent. However, there are also some limitations: (i) the researcher needs to make assumptions, e.g. the normal distribution assumption; (ii) it is challenging to capture contexts, respondents' perspectives and explain some of the respondents' behaviours using pre-determined questions; (iii) it is often expensive to implement due to large sample size; (iv) it is hard to verify inconclusive findings.

On the other hand, qualitative research provides detailed context-specific information due to its flexibility. The researcher can have detailed discussions with the respondent(s), thus gaining complete insights into a phenomenon of interest. There is an opportunity to gain insights into the opportunities and constraints that shaped the respondents' perceptions, beliefs and behaviours. However, there may be some concerns about qualitative research: (i) the sample size is often small and not representative enough to draw inferences from. However, sample size is not central in qualitative research because the researcher aims to achieve a deeper understanding of the targeted respondents' perspectives, experiences or environments; (ii) qualitative research is inductive, therefore the interpretation of results may be influenced by researcher bias (Helper, 2000). To minimize this researcher bias, thematic analysis using targeted software can be used. If carried out in a transparent and replicable way, qualitative research can provide scientifically valuable information that examines the assumptions about individuals' behaviours and interaction (Henrich et al., 2004). Qualitative research may not address causality but can address the complex causal processes.

Due to these different strengths and weaknesses, a synergy arises between quantitative and qualitative research methods, especially where there is dynamism and a complexity of change processes (Rogers, 2009). Using both types of methods helps in triangulating data, hence making high validity causal inferences (Brady et al., 2004). Below we discuss the data collection methods used in the thesis.

1.6.2 Quantitative data

Quantitative data were collected in three waves of household surveys using structured questionnaires under the 3ie TW4/1010 project led by Tegemeo Institute of Agricultural Policy and Development, Egerton University, Kenya. The three-year panel data comprise three cropping years: 2013/14, 2014/15 and 2015/16. Four sub-counties were selected from each district, and 14 villages were randomly selected from each sub-county. Ten households were randomly selected from each village as respondents. In selected villages, improved maize and bean varieties were promoted using demonstration plots and field days.

In 2013/14, 2,133 households were interviewed. In 2014/15, 1,953 households were reached for a second interview. All these households were again interviewed in 2015/16, in addition to 82 households that were interviewed only at baseline. Consequently, attrition from baseline was 8.4 percent in 2014/15 and

4.8 percent in 2015/16. One hundred and eighty households were only interviewed in 2014/15. Some households were not reached in the first, second and/or third waves due to refusals, unavailability, or dissolution of the household.

The surveys captured data at the plot, household, and individual levels. At the individual level, the information sought was farmers' awareness and participation in the demonstration plots, awareness about the specific improved maize and bean varieties promoted, age, education level, relationship to the head, and occupation of each member. Information sought at the household level included land size, distance to extension services, agro-dealers and type of the nearest road. The crop production data were collected at plot level for each season, and consisted of crops grown, acreage under each crop/variety, inputs used, harvest and amount sold.

Chapter 2 uses the final two waves of data from households within reach of the demo plots to assess the participation in the promotion activities and awareness, knowledge, and adoption of the promoted seed. Chapters 3 and 4 use the three-year panel survey data to assess the determinants of adoption and adoption dynamics, and the impact of certified seeds on productivity and income. Chapter 5 uses the initial and final wave to analyse the livelihood strategies, the dynamics of the strategies, the determinants of strategy choice, and the livelihood outcomes.

1.6.3 Qualitative data

Qualitative data were collected from September to October 2017 to get feedback from targeted participants. Data were collected through focus group discussions and in-depth interviews. 16 focus group discussions, 33 farmer interviews, 17 key informant interviews and 16 interviews with demo hosts were conducted using semi-structured questionnaires to guide the researcher during the interviews. During the interviews, the researcher was aided by a research assistant who assisted in interpretation from English to the local language. During the whole data collection process, the interviews were recorded (audio), and detailed notes taken.

Focus group discussions (FGDs) were conducted in each village where the demonstration plots were established. We asked the village elder to invite 12 participants. The village elder was given instructions on the section criteria. First, participants should be able to contribute to the purpose of the FGDs (to know farmers' views about demonstration plots, field days and use of maize and bean improved varieties). Second, participants should include farmers from the host village and neighbouring villages. Third, the number of men and women should be equal. Fourth, the group should consist of both youth (under 35 years) and older people. The FGDs provided an in-depth understanding of how farmers learned about the promoted seeds and the reasons for participating or not participating. Information was also sought on the types of seed used, farmers' perceptions about improved varieties and the reasons for using them, and crop husbandry practices.

For farmer in-depth interviews, respondents were purposively selected from the 3-year panel to cover both farmers who used and did not use the improved seeds promoted. Farmers who mentioned they had planted the promoted seeds were selected to get their views about the performance of these varieties. Detailed information on improved vs. traditional/local maize farming was collected, i.e. benefits and constraints of using improved seed varieties. Farmers who did not plant the seeds were interviewed about their reasons for not doing so.

Key informants were purposively selected, taking into consideration the role they play in the agricultural sector. Key informants included demo hosts, agro-dealers and agricultural extension officers at district and sub-county levels. Information collected covered the distribution process of the improved seed, and related information and farmer involvement in the selected demo hosts and establishment of demonstration plots.

1.6.4 Analytical and empirical methods

The discussion of the analytical and empirical methods used for each research question takes place here.

Chapter 2 uses qualitative methods to assess social, environmental and didactic learning to understand the performance of the demonstration plots, the availability of the promoted technology, how farmers adapt to the promoted technology, and the perceived benefits and constraints that come with the technology. The panel survey data were used to calculate the proportion of farmers who attended demonstration plots/field days and farmers' awareness of and use of the promoted seeds to supplement and inform this analysis.

Chapter 3 applies a mixed method to investigate the adoption dynamics of improved maize varieties. The three-wave panel survey data were used to capture the adoption dynamics in each cropping year. Transition matrices were used to capture the adoption dynamics, while a double hurdle model was used to examine factors influencing the adoption decision. The qualitative results were integrated with qualitative information to capture the farmers' perception of maize seeds/varieties, reasons for adopting, disadopting and crop management practices.

Chapter 4 uses the survey data to examine the impact of certified seed on productivity and income. In this chapter, there is an endogeneity problem because households were not assigned to the treatment group, leading to self-section bias. We used the fixed effects regression with inverse probability weighting (IPW) estimator proposed by (Horvitz & Thompson, 1952) to tackle this issue. The combination of regression analysis and the use of the propensity score as weights produces unbiased estimates if either of the models is properly specified (Imbens & Wooldridge, 2009). However, some identification challenges may remain.

Chapter 5 uses two waves of panel survey data complemented by qualitative data to assess livelihood strategies, determinants and livelihood strategy dynamics in rural households. We use the first and last wave of the survey data only, as labour allocation data were unreliable during the second wave. Livelihood strategies were quantified based on the use of the main rural household assets, which are labour and land (Jansen et al., 2006; Van den Berg, 2010). Cluster analysis was used to derive the livelihood strategies. For each livelihood strategy, the determinants were examined using a multinomial logit model. Transition matrices were used to capture the livelihood strategy dynamics between the two years. Incomes were calculated for each livelihood strategy.

1.7 Outline of the thesis

The structure of the thesis is as follows. Chapter 2 examines the learning process, the interaction between actors involved in the learning process, and factors that hinder the learning process, awareness and adoption of the promoted seeds. We critically assess how three types of learning (social, environmental and didactic) influenced the learning process. Moreover, this chapter discusses farmers perceptions and opinions on the implementation of a program involved in dissemination of information and technology. Chapter 3 investigates the adoption dynamics and factors affecting the adoption decision of improved maize varieties. We explore the adoption dynamics for three years in two scenarios; seed recycled for one season and for three seasons. Chapter 4 extends the analysis to evaluate the impact of the adoption of improved maize varieties on yield, maize income per hectare, and crop income. Chapter 5 examines households' livelihood strategies, dynamics of livelihood strategies, determinants of choices, and outcomes of livelihood strategies. We further analyse the number of crops, crop acreage, yields, amount sold and the use of improved seeds in maize and bean cultivation in each strategy. Chapter 6 presents the synthesis. I discuss the findings, policy implications, and recommendations for future research.

2

Chapter 2

High-yielding Seeds in Unyielding Environments; Examining the Learning Process of Maize and Bean Producers in Eastern and Mid-Western Uganda

Chapter 2

High-yielding Seeds in Unyielding Environments; Examining the Learning Process of Maize and Bean Producers in Eastern and Mid-Western Uganda

Abstract

The learning process is important in introducing a relatively new technology to farmers because it affects the level of awareness and adoption. This paper examines the learning process by which farmers come to a decision to use newly introduced seeds which were promoted through demonstration plots in mid-western and eastern regions of Uganda. A mixed method approach was used for analysis; we used data from focus group discussions, interviews and a survey among 983 individuals. We analyse the underlying mechanisms and interaction between actors (farmers, demo hosts, input sellers and seed company officials) that affect awareness and adoption of technologies. We show that there was low awareness and adoption level among the interviewed respondents. There were constraints in interaction among the actors affecting the learning process. The position and needs of farmers were not considered when determining the distance to the demonstration plots and agro-dealers. The social distance of the demo host affected the awareness and adoption. There were limited efforts in stimulating social learning due to limited interactions among actors, irregular involvement of farmers in demonstrations. This paper shows that interactions among actors and better balance between didactic, social and environmental learning obstructs the learning process and outcomes. These interactions are not visible when the awareness and adoption process is evaluated linearly based on outcome indicators.

Key words: Learning process; social, environmental and didactic learning; new varieties; demonstration plots; Uganda

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2.1 Introduction

There is a continuing effort among donors to stimulate adoption of improved varieties through information dissemination and seed distribution among African farmers. Improved varieties are key to increased yields, higher income and sustainable food security. Despite the benefits of the improved varieties, efforts to information dissemination and seed distribution, adoption rates remain very low (Bold et al., 2017; Duflo et al., 2011). Information and learning constraints are a contributing factor to low adoption (Foster & Rosenzweig, 1995; Shikuku et al., 2019). To overcome these constraints, extension is crucial (Anderson & Feder, 2007; Davis, 2008; Pan et al., 2018). Development initiatives such as the Alliance for a Green Revolution in Africa (AGRA), national governments and researchers apply a variety of approaches to disseminate information to bridge the information gaps (Lambrecht et al., 2014). At the same time, there a clear similarity in that most projects employ a combination of demonstration plots or on-farm experiments, direct communication between project staff and farmers as well as mass media, in recent years increasingly focused on mobile phone applications. In this paper we take a closer look at the information and learning constraints in a seed distribution project in Uganda supported by the AGRA initiative.

The importance of learning is widely acknowledged in the literature on agricultural extension, and most studies include social interactions as a key component (Adegbola & Gardebroek, 2007; BenYishay & Mobarak, 2019; Buck & Alwang, 2011; Moser & Barrett, 2006; Rogers, 2003; Stone, 2007). However, few studies specify the variety of social actors and the different learning dynamics this implies. Stone (2016) identifies three types of interactions. The first are interactions between farmers, or social learning. Important social dynamics by which farmers learn from each other are a sense of being part of the group, leading to copying peers, and a sense of hierarchy, leading to copying prestigious individuals in the group. A second type of interaction is didactic learning, the process by which external agents transfer their interests to farmers. Stone distinguished between three major categories of didacts: governments, commercial companies and non-governmental organisations, each in their own way "acting primarily out of their own interests while claiming to act in the farmer's interests" (2016:10). The third type of interaction, environmental learning, is about the interaction between farmers and their fields. Through observation and interpretation of what happens to the crop in a field, farmers attribute certain observed effects to particular crop varieties, leading to a follow-up decision for the next growing season. For most technology introductions all forms of learning take place simultaneously. The distinction is an analytical lens that provides a better view on the roles and positions of development actors, farmers and the crops as material actors (Glover et al., 2017).

We use this conceptualisation of the learning process to provide an explanation for the overall low adoption rates in the case of a seed distribution project in Uganda, aimed at the uptake of new varieties of maize and beans that in combination with improved crop management practices, outperform varieties commonly used by farmers. The support by AGRA implies a prominent role for local seed companies and agro-dealers that, supported by researchers and extension, are to supply improved seed varieties and other inputs to increase the production of major food crops. In this case, new varieties of maize and beans were introduced through demo plots on fields of selected host farmers in Uganda. The objective of our study was to shed more light on the ways the commercial actors and researchers interacted with the farmers and how this affected information dissemination and learning, leading to wide uptake of the improved seeds. The variety of interactions is perceived in this paper as the learning process. In the project the demonstration plot was the nodal point of the learning process. A demonstration plot is usually set up by external agencies (didacts) to make farmers see 'with their own eyes' what a new technology can do to increase yield or other pursued benefits. However, there are limits to what can be learned when farmers visit demonstration plots only a few times. Demonstration plots thus anticipate a follow-up of social learning between farmers and additional environmental learning in the farmers' fields.

We combine results from a large quantitative survey about the distribution of newly introduced varieties of maize and beans with results from a qualitative analysis of the way the seeds were introduced, tried and used by farmers. Many studies on seed distribution and adoption apply statistical tools and models to analyse factors leading to adoption or rejection quantitatively (Beaman et al., 2018; BenYishay & Mobarak, 2019; Dimara & Skuras, 2003; Ghimire & Huang, 2016; Khonje et al., 2015; Manda et al., 2018; Shikuku et al., 2019). These quantitative studies provide useful insight in distribution patterns and correlations between the distribution of an innovation and other indicators, for example household characteristics, farm assets or selected agro-ecological factors. Qualitative studies provide relevant additional insight in the underlying interaction processes and local dynamics by which farmers include, adjust or reject the innovation offered to them (Almekinders et al., 2019; Glover et al., 2016; Westengen et al., 2019). These interactions and local dynamics are important because they constitute a major part of farmers' learning process, resulting in locally-specific adoption patterns. The main question addressed in this paper is how the survey outcomes, which reveal very limited uptake, can be explained in light of the learning process that took place. The findings of our qualitative study thus build on outcomes of the survey, parts of which are included in the results section.

2.2 Materials and methods

From 2014-2017 data was collected from farmers within reach of in total sixteen demonstration plots in four districts in Uganda: Tororo and Iganga districts in the eastern region and Masindi and Hoima districts in the mid-western region in Uganda. Within each district two sub-counties were randomly selected by the project for setting up demonstration plots. Within each of these eight selected sub-counties, two demonstration sites were set up, based on geographical spreading. The survey comprised a total of 983 households who lived within 30 kms of a demo plot. The households were interviewed 3 times: Early 2014, just before the start of the project, one year later, and two years later. During each survey, data was collected about crop production in the previous 12 months (second growing season of the previous year and first growing season of the current year). More details about the sampling strategy and full analysis the data are provided in Kamau et al. (2018).

The qualitative data for this paper derived from sixteen focus group discussions (FGD)-one in each of the villages with a demo plot, thirteen farmer interviews, seventeen expert interviews and 16 demo host interviews. The FGDs and interviews were held in the villages hosting a demonstration plot. Invitations to participate in an FGD were sent through the village elder. The village elder was asked to include an equal number of men and women, as well as people under age 35 (Table 2.1). The FGDs and interviews were held using translators, audio recording and note taking.

The questions asked in the FGDs covered involvement in the selection of the farmer hosting the demonstration plots, visits of the demonstration plots during 'field days', what was observed in the demonstration plots, and what was taken from the plots to the farmers' fields. We also inquired about what hindered farmers from not attending demonstration plots and not sowing the new varieties.

The interviewed experts were seed company staff, agro-dealers and agricultural extension officers. They were asked about their interactions with farmers, their involvement in selecting demo hosts and establishment of demonstration plots. A subset of thirteen farmers was purposely selected among the survey respondents who grew PH5052and NABE15. These farmers and the demo hosts were asked about the performance of the distributed varieties and other relevant qualities of the varieties.

Table 2.1: Number of interviewees by category

	Districts							
Respondents	Iganga		Tororo		Masindi		Hoima	
	Men	Women	Men	Women	Men	Women	Men	Women
Agricultural officers	3		2	1	1	1	2	1
Agro-dealers		1	2		2		1	
Farmers	1	1	1		2		2	1
Demo hosts	3	1	2	2	2	2	3	1
Focus Groups (4 in each district)	29	29	37	31	28	22	23	26

A general overview of farm characteristics is provided in Table 2.2. Besides these farm activities, other income generating activities were mentioned, for example motorbike taxi services, beer brewing, small businesses/trading and wage labour. Main decisions about crop production were made by the household head, that could be a man or a woman. Men were more involved in maize production, a crop usually planted for sale, whereas women were more engaged in bean production, a crop mainly planted for home consumption. The farmers employed both mono-cropping and intercropping on their fields. In most cases maize was intercropped with pulses (common beans, cowpeas, groundnuts or soybeans). Pulses are also intercropped with cassava and sugarcane at an early stage.

Table 2.2: Involvement of farmers in crop and livestock production

	Districts			
	Iganga	Masindi	Tororo	Hoima
Food crops	Maize, common beans, cassava, sweet potatoes, soya, rice, groundnuts	Maize, common beans, bananas, pigeon peas, groundnuts, cassava, sweet potatoes, millet, Irish potatoes	Maize, common beans, rice, cowpeas, soybeans, groundnuts, cassava, sweet potatoes, millet, sorghum, simsim	Maize, common beans, bananas, pigeon peas, groundnuts, cassava, sweet potatoes, Irish potatoes, millet
Other crops	Coffee	Coffee, sugarcanes, sunflower	Cotton, coffee	Coffee, sugarcanes, tobacco, cocoa
Livestock kept	Cattle, goats, chicken, ducks	Cattle, goats, chicken, pigs	Cattle, goats, chicken, pigs, sheep	Cattle, goats, chicken, pigs

Source: FGDs and farmer interviews

Data were coded through Atlas.ti and analysed along the themes in Table 2.3. Open or in vivo coding was used in the first stage of data analysis by close examination of data (Silver & Lewins, 2014). Selective coding was then carried out searching for themes and concepts. Stata was used to analyse survey data and calculate the proportion of farmers who visited demonstration plots, were aware and adopted the promoted seeds.

Table 2.3: Themes identified in the data

Farmer and farm characteristics • Main occupation • Sources of income • Types of crops grown • Types of livestock kept
Involvement and Interactions • Involvement of farmers, extension officers during selection of the demo host • Interactions between farmers and demo hosts • Interactions between the seed company staff and farmers • Interactions between the seed company staff and agricultural extension officers at local level
Characteristics of the new varieties • What did farmers like and not like about the PH5052 maize variety • What did farmers like and not like about the NABE15 bean variety
Awareness and adoption • How many farmers are aware of the promoted varieties? • How many farmers planted the promoted varieties? • Reasons for not planting the promoted varieties
Constraints and challenges • Reasons for not approaching the demo hosts for advice • Reasons for not attending the field days

2.3 Results

2.3.1 Implementation of the demonstration plots and farmers' involvement

The seed company was responsible for selection and training of the demo hosts, establishing and monitoring the plots, and providing inputs. They identified potential demonstration plots based on suitability, identified and approached the landowner, and drew a list of those willing to host. The final hosts were then randomly selected from the list. Demo hosts were asked to set aside one acre of their land for demonstration plots, 0.5 acre for the new maize variety (PH5052) and 0.5 acre for the new bean variety (NABE15). Demonstration plots were expected to be operational in four consecutive seasons as shown in Table 2.4. In the first project season (second growing season of 2014), demonstration plots were established in 12 out of 16 villages. In early 2015 season all 16 villages had a demonstration plot. In following seasons two demo hosts did not plant. As one of the experts expressed: "When identifying a farmer to host the demonstration plot, choose a farmer who is well prepared to grow that crop in that season. A farmer may be willing to offer land but not prepared to grow and take care of the crop. Therefore, he will not take care of the garden e.g. weeding on time or chasing away the animals. He should also be willing to teach other farmers." Some demo hosts belonged to a farmer group, in which case group members were involved in the maintenance of the demonstration plot and received part of the harvest (interview notes, 2017).

During field days agro-dealers and seed company staff attended the plots. Agro-dealers, based in the main district town, were responsible for having new seed varieties in stock for farmers who wanted to buy for their own fields. To increase the awareness of the demonstration plot and the variety on the plot, a signpost was erected on each demonstration site indicating the variety planted, recommended spacing, maturity period and expected yield. According to the seed company, the maize and bean varieties have high yield potential, are drought tolerant, and have a short maturity period. PH5052 is resistant to northern leaf blight and maize streak virus, and tolerant to grey leaf spot. NABE15 is best suited for low-mid altitude areas, resistant to Anthracnose, bean rust and halo blight and tolerant to root rot, common bean blight and angular leaf report.

Table 2.4: Seasonal calendar for the demonstration plots and field days as planned

	Season 1											Season 2
	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Project activities			Training of demo hosts Delivery of seed and DAP	Monitoring of demonstration plots/delivery of UREA Training of demo hosts	Creating awareness of the field day Field day				Training of demo hosts Delivery of seed and DAP	Monitoring of demonstration plots/delivery of UREA Training of demo hosts	Creating awareness of the field day Field day	
Cropping calendar		Land preparation	Planting and base dressing	Weeding and top dressing	Field day Harvesting beans	Harvesting maize		Land preparation	Planting and base dressing	Weeding and top dressing	Harvesting beans	Harvesting maize

The materials provided by the seed company consisted of 5kgs of seed of PH5052 and NABE15 each and fertiliser (25kgs of DAP, 25kgs of UREA for maize and 25kgs of NPK171717 for common beans). The seed company staff trained demo hosts in land preparation, plant spacing and fertiliser application. They returned a month after planting to monitor the crop performance and deliver the top-dressing fertiliser (UREA). The return visit was also used to train demo hosts on weeding and pest control.

The demo hosts were responsible for organising enough labour for land preparation, planting, fertiliser application, weeding, pesticide application and harvesting. The demo host could take the harvest for sale or consumption. It was assumed that the demo hosts would inform and instruct other farmers, during field days and other moments when interacting with farmers. The demo hosts were instructed to mobilize farmers to attend the field day. In addition, announcements were made through the radio one week prior to the field day. To further train farmers on the promoted seeds, field days were held at the demonstration plots/sites when the maize crop reached maturity.

During the field day, seed company officials probed farmers' perception of the new seed varieties through a question and answer session. Agro-dealers gave the retail price of the new seed and explained the location of their shops to the farmers. Leaflets with information in English and the local language (Lunyoro in Masindi and Hoima districts, Lusoga in Iganga district and Japadhola in Tororo district) were handed out to farmers. The seed company staff also offered instructions on fertiliser application and spacing for planting. Moreover, there were government extension officers who were helping the seed company officials and agro dealers in providing information to the farmers.

One element of the instructions was to identify improved seeds from fake copies. Official seed packages had a scratch card and included details on the seed type, quantity, expiry date and the name of the company. Scratching the card revealed a 12-digit number that farmers could enter as an SMS text message to a given phone number. An automated return message would indicate if the seed was original or fake.

To sum up, the demonstration plots aimed to convince farmers to buy the improved seed varieties. The main didacts were the seed company officials, agro dealers and government extension officers, providing instructions to the demo host and information to the farmers attending the field days. Extension officers and agro-dealers could provide follow-up guidance for farmers who were willing to buy the seeds. In the next section we further analyse how this didactic learning was connected to the social and environmental learning.

2.3.2 Farmers' involvement in demonstration plots and attendance to field days

There were several challenges in running the demo plots. Two of the selected demo hosts were not willing to continue with the demonstration plot after the first seasons. Other demonstration plots were not well maintained, for example late weeding or not applying the provided fertiliser. As a result, these demonstration plots looked very much like what the farmers were used to. Some plots were destroyed by animals. There were also demo hosts who did little or nothing to share information with other farmers. Data retrieved from project reports show that there was low turnout during the field days with around 45-87 farmers per field day (Table 2.5) and 5 percent of the farmers in our survey (Table 2.6). In addition, only one field day was conducted per successful demonstration plot per season, and field days were cancelled when the crops did not look well in the demo plot. As indicated before, field days were held when the maize crop reached maturity. By then, the bean crop had already been harvested. Farmers expressed their unease with this timing during the FGDs and suggested that field days should be carried out the beginning and end of the growing phase for both maize and beans.

Table 2.5: Number of farmers that attended field days

Season	Number of field days	Number of attendants
2014/15 Season 1	9	426
2014/15 Season 2	7	320
2015/16 Season 1	5	435
2016/17 Season 2	10	534

Source: Technical reports

Attendance was highest in Tororo district (See detailed analysis at village level in Table A2.1 in the Appendix). For the demonstration plot in Akwedi village in Tororo district, more than half of the interviewed farmers reported to have visited the demonstration plots/field days in the second year.

Farmers in the FGD we did in that village had a good relationship with the demo host and he was sharing information.

Table 2.6: Percentage of survey farmers that participated the demonstration plots/attended field days

	Full sample		Male farmers		Female farmers	
Year	N	Percentage	N	Percentage	N	Percentage
First year (2014/15)	1644	4.9	763	6.9	881	3.2
Second year (2015/16)	1821	5.4	865	7.1	956	4.0

Source: Survey data

All farmers within a radius of about 30 kilometres were supposed to receive information about the location of demo plots and the opportunity to visit a demo plot in areas where demonstration plots were established. Radio announcements were made a week before the field days. Demo hosts were also expected to mobilize farmers, but this was often limited to the farmers they already knew. Hence, farmers who lived far from the demonstration plots were particularly vulnerable to exclusion.

Whereas more could have been done to announce the field days, information as such appeared not the only trigger of low attendance rates. Farmers indicated several factors that help explain the low turnout. Some farmers expressed they did not attend demonstration plots because they were not involved in selection of the demo host. As one farmer put it: “The field days are successful if the seed company involves the farmers’ association or groups. If the seed company deals with a farmer who is not favoured by other farmers, then there is low turnout.” Another farmer expressed: “Some demo hosts were favoured by the seed company because they were selected multiple times to host the demonstration plots even prior to the promotion of PH5052 and NABE15.” This factor was confirmed by seed company staff, explaining that villagers were not always happy with the allocation of demonstration plots. One of the farmers said that there were several demonstration plots in the area, but he just passed them “because he is never invited.” In some areas, respondents could not identify who the demo host was or were unaware of the demonstration garden in their village. How precarious the balance between curiosity and trust can be is expressed by one farmer saying that: “We used to see signposts along the way but did not have prior information about the demonstration plot. We were afraid to go to the farm because the owner may accuse you if anything goes wrong in his farm.”

2.3.3 Connections between demonstration plots and farmers’ fields

The survey data show an overall low awareness of the PH5052 and NABE15 varieties, though awareness slightly increased in subsequent years (Table 2.7). Only 1-3% of the survey respondents were aware of PH5052 and NABE15. Note that this is even less than the share of respondents who participated in the field days. Of those who participated, awareness was 17 percent in the first year of the intervention and only 9 percent in the second year. On average, farmers gave correct answers to about 25% of the knowledge questions about the promoted varieties, and this did not change between years. This score was substantially higher for those that participated in the field days: 38-53%. Gender differences are small. A detailed analysis per village is presented in Table A2.2 and Table A2.3 in the Appendix. Awareness and knowledge of the promoted varieties was high among the farmers who participated in the FGDs in the villages with demo plots, especially among members of farmer groups (Table 2.8). Farmers who were aware of the new seed varieties mentioned there were differences in performance of the varieties in terms of production compared to their own crops (FGD, interviews). For example, they mentioned that the maize varieties produced more than one cob per plant.

Table 2.7: Awareness and knowledge of PH5052 and NABE15 among interviewed farmers by participation and gender

Percentage aware of variety	Full sample		Participants		Non-participants		Male farmers		Female farmers	
	N	%	N	%	N	%	N	%	N	%
PH5052										
Pre-intervention (2013/14)	1366	0.8	0	0	1366	0.8	642	1.2	724	0.4
First year (2014/15)	1644	2.7	81	17.3	1563	2.0	763	3.4	881	0.2
Second year (2015/16)	1821	2.9	99	9.1	1722	2.5	865	2.9	956	2.8
NABE15										
Pre-intervention (2013/14)	1366	1.0	0	0	1366	1.0	642	1.2	724	0.7
First year (2014/15)	1644	2.0	81	10.0	1563	1.6	763	2.6	881	1.5
Second year (2015/16)	1821	2.1	99	6.1	1722	2.0	865	2.3	956	2.0
Share of knowledge questions answered correctly (for respondents who were aware)[1]										
	Full sample		Participants		Non-participants		Male		Female	
	N	Score	N	Score	N	Score	N	Score	N	Score
PH5052										
First year (2014/15)	260	0.27 (0.25)	43	0.53 (0.22)	217	0.22 (0.22)	164	0.26 (0.18)	96	0.28 (0.25)
Second year (2015/16)	280	0.27 (0.26)	30	0.39 (0.29)	250	0.26 (0.25)	142	0.28 (0.26)	138	0.27 (0.25)
NABE15										
First year (2014/15)	173	0.24 (0.24)	29	0.39 (0.27)	144	0.21 (0.22)	92	0.27 (0.24)	81	0.22 (0.23)
Second year (2015/16)	260	0.27 (0.25)	21	0.38 (0.24)	167	0.23 (0.23)	164	0.26 (0.18)	96	0.28 (0.25)

Notes: standard deviations in parentheses. [1]Farmers who were aware of the promoted varieties were asked 17 questions on the knowledge about the varieties' attributes and improved farming practices.

Table 2.8: Number and percentage of farmers reporting awareness of promoted seeds of FGD participants

District	Sub-county	Village	Number of farmers aware (% in bracket) PH5052	NABE15
Hoima	Kiziranfumbi	Kicaaya (N=12)	12(100)	12(100)
		Muteme-Kinywambeho (N=13)	0(0)	0(0)
	Kyabigambire	Kiranga (N=12)	11(91.7)	12(100)
		Kitongole-Kiryankima (N=12)	0(0)	0(0)
Masindi	Karujubu	Kihuuba (N=11)	11(100)	11(100)
		Kibwona (N=12)	0(0)	0(0)
	Pakanyi	Kilanyi (N=14)	3(21.4)	1(7.1)
		Kyakamese (N=13)	9(69.2)	13(100)
Tororo	Kirewa	Akwedi-Katandi (N=25)	25(100)	25(100)
		Mifumi-South (N=12)	10(83.3)	4(33.3)
	Nagongera	Namwaya (N=19)	16(84.2)	3(15.8)
		Pokongo (N=12)	0(0)	0(0)
Iganga	Igombe	Bulyansime (N=15)	3(20)	2(13.3)
		Bubenge A (N=8)	0(0)	0(0)
	Nambale	Naibiri-North (N=17)	1(5.9)	0(0)
		Nabitovu-South (N=18)	18(100)	18(100)

Source: Focus Group Discussions (2017)

During field days, farmers were told by the present agro-dealers where to buy the promoted seed. As shown in Table 2.9, the adoption rate was very low: less than one percent of the interviewed respondents reported planting PH5052 or NABE15 across the two years, resulting in a low acreage with the promoted seeds. Also, FGD participants, who were relatively well-aware of the promoted varieties, revealed low adoption rates, although these differed substantially between villages (Table 2.10). Interestingly, adoption rates were low even among the demo hosts. Only nine of the sixteen hosts planted the new varieties in the year after the project: six planted the PH5052 maize variety and three NABE15. Two demo hosts who planted PH5052 took seed from the previous harvest while the remaining four bought certified seed. All the demo hosts who planted NABE15 took seed from their own stock.

Results from FGDs show that some farmers who attended the demonstrations said they did not buy the varieties but are practising the row planting and weeding on other maize varieties. These are low-cost adjustments that mainly require additional labour but no financial investments. But also, labour is a scarce resource, and many of the interviewed farmers expressed they found the recommended crop management too labour intensive.

Table 2.9: Percentage of households and acreage who planted PH5052 and NABE15 (N=983)

	PH5052		NABE15	
	Season 2	Season 1	Season 2	Season 1
Percentage of farmers				
First year (2014/15)	0.3	0.2	0.2	0.1
Second year (2015/16)	0.2	0.2	0.2	0
Acreage under PH5052 and NABE15				
First year (2014/15)	0.002	0.002	0.003	0.001
Second year (2015/16)	0.005	0.001	0.001	0.000

Source: Survey data

Table 2.10: Number and percentage of FGD participants who planted the promoted seeds by (for those who were aware of PH5052 and NABE15)

			(% in brackets)	
District	Sub-county	Village	PH5052	NABE15
	Kiziranfumbi	Kicaaya (N=12)	0(0)	0(0)
Hoima	Kyabigambire	Kiranga (N=12)	0(0)	0(0)
	Karujubu	Kihuuba (N=11)	4(33.3)	1(8.3)
		Kilanyi (N=14)	0(0)	0(0)
Masindi	Pakanyi	Kyakamese (N=13)	2(15.4)	6(46.2)
		Akwedi-Katandi (N=25)	3(12)	5(20)
	Kirewa	Mifumi- South (N=12)	10(83.3)	4(33.3)
Tororo	Nagongera	Namwaya (N=19)	7(36.8)	0(0)
	Igombe	Bulyansime (N=15)	0(0)	0(0)
		Naibiri-North (N=17)	0(0)	0(0)
Iganga	Nambale	Nabitovu-South (N=18)	0(0)	0(0)

Source: Focus Group Discussions (2017)

Farmers who planted PH5052 mentioned that they got good yields and generated additional income (FGDs and farmer interviews, 2017). Farmers who did not plant the new varieties mentioned that agrodealers were located in town centres far away from the villages, making accessibility difficult. Farmers who took the effort to buy the seed sometimes found no seeds at the shop. Agro-dealers confirmed that seeds were not always available due to delayed delivery, in particular in the first season. Farmers also explained that they did not plant the new seeds due to the high seed price and poor seed quality. The cost of the PH5052 maize seed was 6500-7000 UGX/kg compared to OPVs which sold at 2000-3000 UGX/kg. There were additional complications in the adoption of the improved bean variety, primarily the limited marketing options. One of the demo host in Kiranga village mentioned that she tried selling the bean harvest to the neighbours, who refused because they preferred their own varieties. Most farmers preferred home-saved bean seed to certified bean seed.

2.4 Discussion and conclusion

Our examination of learning effects through the implementation of demonstration plots complemented with field days to promote new maize and been varieties confirms the importance of social interactions, including interactions with material inputs and the agro-ecological environment. The project experience limited success: our survey shows low awareness and adoption rates. The qualitative study, that was set up in addition to survey results, reveals important insights about the interaction dynamics between the different actors involved in the seed distribution process. It appeared that the project setup constrained many crucial interactions that would generate a learning process. Our findings are not unique and confirm findings from other studies on the limited effects of demonstration plots (Kondylis & Mueller, 2013).

The framework from Stone (2016) about the learning process underlying the introduction of improved seeds as a combination of didactic, social and environmental learning sheds interesting light on the above findings. Didactic learning formed the core of the intervention, and it was implicitly assumed that either this in itself was enough or would trigger sufficient social and environmental learning to induce adoption. Neither appeared to be the case: the knowledge spread was very limited and adoption rates were low. The setup of the didactic learning process can explain this lack of success at least partly.

Our analysis indicates that the didacts did not really consider the position and needs of the local farmers. The promoted seeds were supposed to be accessible, but the distance between farmers and agrodealers was large, seeds were not always available and seed prices were high. In addition, contrary to farmers' needs, they organized only one field day per season. Perhaps most importantly, farmers were not involved in the selection of the demo hosts. The didacts wrongly assumed that spontaneous mouth-to-mouth promotion, signposts at the demo plots, and limited radio announcements would be sufficient promotion for the demo plots. In reality, the information dissemination process is complex and is mediated by the social position of demo hosts and existing interactions patterns. This is confirmed by our finding that in situations where demo hosts were part of an existing farmer group, participation in field days and seed adoption rates were higher. Other studies confirm the importance of prior existing networks and farmer groups (Ainembabazi et al., 2017; BenYishay & Mobarak, 2019; Kroma, 2006).

It is somewhat remarkable that the project spent so little effort on stimulating social learning effects. There are many examples in the literature that show increased effects when farmers are more involved in the establishment, lay-out and management of demonstration plots (Dar et al., 2019; Fliert et al., 2010). This also relates to the frequency of interactions: regular involvement of farmers in demonstrations and on-farm experiments increase learning (Flor et al., 2017).

The didacts active in the demonstration plots are primarily commercial actors. The one-off field days and presence of agro-dealers suggest that informing farmers about where to buy seeds was considered more important than explaining farmers how to grow these seeds profitably. The commercial nature of the field days and demonstrations plots was not unnoticed by the farmers and had negative consequences for the social learning. Our interviews with farmers revealed that some farmers avoided contact with the demo hosts as they suspected favouritism rather than genuine sharing of information. Financial benefits are common but our findings confirm other studies emphasizing that benefits need to be distributed equally among participants (BenYishay & Mobarak, 2019; Shikuku et al., 2019; Taylor & Bhasme, 2018). Moreover, our findings suggest that the commercial interests of the didacts were primarily focused on selling seeds of a bean variety which was not preferred by buyers. This comes out most clearly from the way the bean variety was incorporated in the farming practices. Introducing a bean variety with the assumption that both improved seeds and harvest can be sold indiscriminately underestimates the importance of qualities and social ties affecting the value attached to a particular variety, making the promoted bean variety more an anti-commodity than a commodity (Hazareesingh & Maat, 2016).

The restricted focus on commercialisation of improved varieties in the didactic learning process and the limited attention given to the social and environmental learning explains the limited awareness and adoption rates of the introduced seed varieties. Demonstration plots can either be successful or unsuccessful in disseminating information to create awareness on improved technologies. Examples of successful stories are shown in Kondylis and Mueller (2013), Kondylis et al. (2017) and Matsumoto et al. (2013). However, we do not suggest that adoption rates would have been higher with more attention for a better balance between didactic, social and environmental learning. The main conclusion from our study is that the imbalance between different types of learning obstructs learning outcomes at both ends. The flawed design and implementation of demonstration fields as well as the lack of follow-up in terms of guiding and monitoring the emulation reduces the number of farmers that could have experimented with the new seeds and related crop management practices. It also thwarts the options for project managers and implementers to learn from farmers' learning.

Appendix

Table A2.1: Number and percentage of survey farmers that visited demonstration plots/attended field days (only villages with participation are mentioned)

	District	Village	N	Full sample	N	Female	N	Male
First year (2014/15)	Hoima	Kinywamgeho	12	2 (16.67)			4	2 (50.00)
		Kisambya	14	1 (7.14)			6	1 (16.67)
		Kihoro	12	1 (8.33)			5	1 (20.00)
		Kasinina	15	1 (6.67)	7	1 (14.29)		
		Kiranga	14	1 (7.14)			7	1 (14.29)
		Kyarubanga	16	3 (18.75)			9	3 (37.50)
		Nyakabingo	17	1 (5.88)			9	1 (11.11)
	Masindi	Kinogozi a	8	2 (25.00)			4	2 (50.00)
		Kyaruganga	12	1 (8.33)			6	1 (16.67)
		Kihanguzi B	9	3 (33.33)			6	3 (50.00)
		Nyakyanika	10	1 (10.00)	5	1 (20.00)		
		Kajumba	19	1 (5.26)			10	1 (10.00)
		Kyakamese	15	3 (20)	9	2 (22.22)	6	1 (16.67)
	Tororo	Akwedi	16	5 (31.25)	9	2 (22.22)	7	3 (42.86)
		Katandi	18	1 (5.56)	11	1 (9.09)		
		Nyagulu	20	2 (10.00)	10	1 (10.00)	10	1 (10.00)
		Sele	17	3 (17.65)	9	1 (11.11)	8	2 (25.00)
		Simwenge	16	2 (12.5)	8	1 (12.5)	8	1 (12.5)
		Mifumi-south	14	4 (28.57)	8	1 (12.5)	6	3 (50.00)
		Nyamiyemba	15	1 (6.67)			6	1 (16.67)
		Winyaka	17	1 (5.88)			9	1 (11.11)
		Pamagode	18	2 (11.11)	9	1 (11.11)	9	1 (11.11)
		Bulalo	18	1 (5.56)	9	1 (11.11)		
		Iyolwa	19	4 (21.05)	10	1 (10.00)	9	3 (33.33)
		Nyakatooke	14	3 (21.43)	7	1 (14.29)	7	2 (28.57)
		Sindila	16	4 (25.00)	10	2 (20.00)	6	2 (33.33)
		Akandi	19	3 (15.79)			10	3 (30.00)
		Mukwana mo	18	3 (16.67)	10	1 (10.00)	8	2 (25.00)
		Soni Ogwa	7	1 (14.29)	3	1 (33.33)		
		Maoundo west	18	2 (11.11)	10	1 (10.00)	8	1 (12.50)
		Pokong plain	22	1 (4.55)	12	1 (8.33)		
		Kadewele	16	1 (6.25)			8	1 (12.50)
		Namwaya central	19	1 (5.26)	9	1 (11.11)		
		Okuta	17	2 (11.76)	10	1 (10.00)	7	1 (14.29)
		Pomede	17	2 (11.76)	9	1 (11.11)	8	1 (12.50)

	Iganga	Bubenge a	15	2 (13.33)	9	1 (11.11)	6	1 (16.67)
		Bulyansime	15	2 (13.33)			7	2 (28.27)
		Bubinga	19	1 (5.26)	10	1 (10.00)		
		Walanga	13	3 (23.08)	7	1 (14.29)	6	2 (33.33)
		Naibiri central	11	1 (9.09)			5	1 (20.00)
		Nambale 1	14	1 (7.14)			6	1 (16.67)
		Kakira	13	1 (7.69)	6	1 (16.67)		
Second year (2015/16)	Hoima	Rumogi	19	1 (5.26)			9	1 (11.11)
		Kicomyo	32	1 (3.13)	16	1 (6.25)		
		Kihambya	16	1 (6.25)	8	1 (12.50)		
		Kyakamese	17	1 (5.88)			9	1 (11.11)
		Kasinina	16	1 (6.25)	8	1 (12.50)		
		Kiranga	17	1 (5.88)			8	1 (12.50)
		Karungu	17	2 (11.76)	10	1 (10.00)	7	1 (14.29)
		Kiherwa	18	1 (5.56)			9	1 (11.11)
	Masindi	Buryango i	15	2 (13.33)	8	1 (12.50)	7	1 (14.29)
		Buryango ii	16	1 (6.25)	8	1 (12.50)		
		Kyabadindi	18	1 (5.56)			9	1 (11.11)
		Kamuyonga	13	1 (7.69)			6	1 (16.67)
		Kihuuba	14	2 (14.29)	8	1 (12.50)	6	1 (16.67)
		Kizindizi	10	1 (10.00)			5	1 (20.00)
		Kyaruganga	15	1 (6.67)	9	1 (11.11)		
		Kidwera	18	3 (16.67)			9	3 (33.33)
		Kihanguzi B	12	1 (8.33)			6	1 (16.67)
		Kituuka ii	16	3 (18.75)	8	1 (12.50)	8	2 (25.00)
		Nyakyanika	10	1 (10.00)			5	1 (20.00)
		Kajumba	19	1 (5.26)			10	1 (10.00)
		Katuugo B	17	1 (5.88)			9	1 (11.11)
		Kisindi	15	1 (6.67)	8	1 (12.50)		
		Kyakamese	18	5 (27.78)	10	3 (30.00)	7	8 (25.00)
		Kyababyara	14	2 (14.29)	7	1 (14.29)	7	1 (14.29)
	Tororo	Akwedi	16	10 (62.50)	9	4 (44.44)	6	7 (85.71)
		Katandi	19	1 (5.26)	11	1 (9.09)		
		Nyagulu	20	4 (20.00)	10	1 (10.00)	10	3 (30.00)
		Sele	19	2 (10.53)	10	1 (10.00)	9	1 (11.11)
		Simwenge	18	1 (5.56)			9	1 (11.11)
		Mifumi-south	17	2 (11.76)	9	1 (11.11)	9	1 (11.11)
		Nyabanja	18	1 (5.56)			9	1 (11.11)
		Nyamiyemba	17	2 (11.76)			6	2 (33.33)
		Winyaka	17	1 (5.88)	8	1 (12.50)		

		Bulalo	18	1 (5.56)			9	1 (11.11)
		Iyolwa	19	2 (10.53)	10	1 (10.00)	9	1 (11.11)
		Nyakatooke	14	1 (7.14)	7	1 (14.29)		
		Sindila	20	1 (5.00)			10	1 (10.00)
		Pokong peny 1	19	1 (5.26)	11	1 (9.09)		
		Pokong peny 2	10	1 (10.00)	5	1 (20.00)		
		Pokong plain	23	1 (8.70)	13	1 (7.69)	10	1 (10.00)
		Kadewele	17	2 (11.76)			9	2 (22.22)
		Okuta	17	1 (5.88)	10	1 (10.00)		
	Iganga	Bubenge a	18	1 (5.56)			8	1 (12.50)
		Bulyansime	17	4 (23.53)			7	1 (14.29)
		Igombe	18	2 (11.11)	10	1 (10.00)	8	1 (12.50)
		Namakunyu	19	1 (5.26)	10	1 (10.00)		
		Bubinga	20	1 (5.00)	10	1 (10.00)		
		Businda	16	1 (6.25)			8	1 (12.50)
		Kikunyu	19	2 (10.53)	10	1 (10.00)	9	1 (11.11)
		Nawapendo	14	2 (14.29)	7	1 (14.29)	7	1 (14.29)
		Walanga	14	3 (21.43)	7	2 (28.57)	7	1 (14.29)
		Muira	19	2 (10.53)	9	2 (22.22)		
		Nabitovu north	28	1 (3.57)	14	1 (7.14)		
		Bulondo	19	1 (5.26)			9	1 (11.11)
		Nambale i	16	4 (25.00)	8	1 (12.50)	8	3 (37.50)
		Nambale ii	19	2 (10.53)			10	2 (20.00)

Source: Survey data

Table A2.2: Awareness of PH5052 (Farmers should have mentioned PH5052 as one of the varieties)

			Full sample		Female		Male	
	District	Village	N	% in parenthesis	N	% in parenthesis	N	% in parenthesis
Year 1	Hoima	Kinyawamgeho	12	1 (8.33)			4	1 (25.00)
(2014/15)	Tororo	Akwedi	16	6 (37.50)	9	2 (22.22)	7	4 (57.14)
		Katandi	18	2 (11.11)	11	1 (9.09)	7	1 (14.29)
		Nyagulu	20	3 (15.00)	10	1 (10.00)	10	2 (20.00)
		Sele	17	5 (29.41)	9	2 (22.22)	8	3 (37.50)
		Simwenge	16	1 (6.25)			8	1 (12.50)
		Mifumi south	14	4 (28.57)	8	3 (37.50)	6	1 (16.67)
		Nyabanja	17	3 (17.65)	9	2 (22.22)	8	1 (12.50)
		Nyamiyemba	15	3 (20.00)	9	3 (33.33)		
		Winyaka	17	1 (5.88)			9	1 (11.11)
		Pamagode	18	3 (16.67)	9	1 (11.11)	9	2 (22.22)

		Bulalo	18	1 (5.56)	9	1 (11.11)		
		Nyakatooke	16	1 (6.25)	7	2 (28.57)	7	3 (42.86)
		Pokongo plain	22	2 (9.09)	12	1 (8.33)	10	1 (10.00)
	Iganga	Bubenge a	15	1 (6.67)			6	1 (16.67)
		Bulyansime	15	2 (13.33)			7	2 (28.57)
		Nambale i	18	1 (5.56)			10	1 (10.00)
Year 2 (2015/16)	Hoima	Kinyawamgeho	15	1 (6.67)	8	1 (12.50)		
	Tororo	Akwedi	16	6 (37.50)	9	3 (33.33)	7	3 (42.86)
		Katandi	19	2 (10.53)	11	1 (9.09)	8	1 (12.50)
		Nyagulu	20	3 (15.00)	10	1 (10.00)	10	2 (20.00)
		Sele	19	5 (26.32)	10	2 (20.00)	9	3 (33.33)
		Simwenge	18	2 (11.11)	9	1 (11.11)	9	1 (11.11)
		Mifumi south	17	5 (35.29)	9	3 (33.33)	8	3 (37.50)
		Nyabanja	18	4 (22.22)	9	2 (22.22)	9	2 (22.22)
		Nyamiyemba	17	4 (23.53)	9	3 (33.33)	8	1 (12.50)
		Winyaka	17	1 (5.88)	8	1 (12.50)		
		Pamagode	19	3 (15.79)	10	1 (10.00)	9	2 (22.22)
		Bulalo	18	1 (5.56)			9	1 (11.11)
		Nyakatooke	14	5 (35.71)	7	3 (42.86)	7	2 (28.57)
		Sindila	20	1(5.00)	10	1(10.00)		
	Iganga	Pokong plain	23	2(8.70)	13	1 (7.69)	10	1 (10.00)
		Bubenge a	18	1 (5.56)	10	1 (10.00)		
		Bulyansime	17	4 (23.53)	10	1 (10.00)	7	2 (28.57)
		Nambale i	19	1 (5.26)			10	1 (10.00)

Source: Survey data

Table A2.3: Awareness of NABE15 (Farmers should have mentioned NABE15 as one of the varieties)

	District	Village	N	Full sample	N	Female	N	Male
Year 2 (2014/15)	Hoima	Kanyegaramu	18	1 (5.56)			8	1 (12.50)
		Bwizibwera	18	1 (5.56)			9	1 (11.11)
		Ruhunga	15	1 (6.67)			7	1 (14.29)
	Masindi	Buryango ii	11	1 (9.09)			4	1 (25.00)
		Kajumba	19	1 (5.26)	9	1 (11.11)		
	Tororo	Akwedi	16	5 (31.25)	9	1 (11.11)	7	4 (57.14)
		Katandi	18	2 (11.11)	11	1 (9.09)	7	1 (14.29)
		Nyagulu	20	2 (10.00)	10	2 (20.00)		
		Sele	17	1 (5.88)			8	1 (12.50)
		Simwenge	16	1 (6.25)			8	1 (12.50)

		Mifumi south	14	1 (7.14)			6	1 (16.67)
		Nyabanja	17	1 (5.88)			9	1 (11.11)
		Nyamiyemba	15	2 (13.33)			9	2 (22.22)
		Winyaka	17	2 (11.76)			9	2 (22.22)
		Iyolwa	19	1 (5.26)	10	1 (10.00)		
		Nyakatooke	14	1 (7.14)			7	1 (14.29)
		Pokongo plain	22	3 (13.64)	12	2 (16.67)	10	1 (10.00)
		Namwaya central	19	1 (5.26)			10	1 (10.00)
		Okuta	17	1 (11.76)			7	1 (14.29)
	Iganga	Bulyansime	15	1 (6.67)			7	1 (14.29)
		Butalango	15	1 (6.67)	10	1 (10.00)		
		Igombe	16	2 (12.50)	10	1 (10.00)	6	1 (16.67)
Year 3 (2015/16)	Hoima	Kanyegaramu	20	1 (5.00)	10	1 (10.00)		
		Bwizibwera	20	2 (10.00)	10	1 (10.00)		
		Ruhunga	18	1 (5.56)			9	1 (11.11)
	Masindi	Buryango ii	16	1 (6.25)	8	1 (12.50)		
		Kajumba	19	1 (5.26)			10	1 (10.00)
	Tororo	Akwedi	16	5 (31.25)	9	2 (22.22)	7	3 (42.86)
		Katandi	19	2 (10.53)	11	1 (9.09)	8	1 (12.50)
		Nyagulu	20	2 (10.00)	10	1 (10.00)	10	1 (10.00)
		Sele	19	1 (5.26)	9	1 (11.11)		
		Simwenge	18	2 (11.11)	9	1 (11.11)	9	1 (11.11)
		Mifumi south	17	1 (5.88)	9	1 (11.11)		
		Nyabanja	18	2 (11.11)	9	1 (11.11)	9	1 (11.11)
		Nyamiyemba	17	3 (17.65)	9	2 (22.22)	8	1 (12.50)
		Winyaka	17	2 (11.76)	8	2 (25.00)		
		Iyolwa	19	1 (5.26)	10	1 (10.00)		
		Nyakatooke	14	1 (7.14)	7	1 (14.29)		
		Pokongo plain	23	3 (13.04)	13	1 (7.69)	10	1 (20.00)
		Namwaya central	20	1 (5.00)			11	1 (9.09)
		Okuta	17	1 (5.88)			7	1 (14.29)
	Iganga	Bulyansime	17	2 (11.76)	10	1 (10.00)	7	1 (14.29)
		Butalango	19	2 (10.53)	10	1 (10.00)	9	1 (11.11)
		Igombe	18	2 (11.11)	10	1 (10.00)	8	1 (12.50)

Source: Survey data

Table A2.4: Number and percentage of households that planted PH5052 and NABE15 (N=983)

		Number (%)	Location: District, village (number)
PH5052			
Year 1 (2014/15)	season 1	3(3)	Tororo, Akwedi (2); Tororo, Sele (1)
	season 2	2 (2)	Tororo, Akwedi (2)
Year 2 (2015/16)	season 1	2(2)	Tororo, Akwedi (1); Tororo, Namwaya central (1)
	season 2	2(1)	Tororo, Akwedi (2)
NABE15			
Year 1 (2014/15)	season 1	2(02)	Tororo, Winyaka (1); Hoima, Bwizibwera (1)
	season 2	1(0.001)	Tororo, Winyaka (1)
Year 2 (2015/16)	season 1	2(0.002)	Tororo, Akwedi (2)
	Season 2	0 (0)	

Source: Survey data. There were zero respondents who planted PH5052 and NABE15 in all the villages not included on the table

Table A2.5: Acreage under PH5052 and NABE15 (N=983)

		Mean acreage	Location: District, village (mean acreage)
PH5052			
Year 1 (2014/15)	season 1	0.002	Tororo, Akwedi (0.19); Tororo, Sele (0.05)
	season 2	0.001	Tororo, Akwedi (0.20)
Year 2 (2015/16)	season 1	0.005	Tororo, Akwedi (0.33); Tororo, Namwaya central (0.20)
	season 2	0.001	Tororo, Akwedi (0.16)
NABE15			
Year 1 (2014/15)	season 1	0.003	Tororo, Winyaka (0.11); Hoima, Bwizibwera (0.24)
	season 2	0.001	Tororo, Winyaka (0.11)
Year 2 (2015/16)	season 1	0.002	Tororo, Akwedi (0.13)
	Season 2	0 (0)	

Source: Survey data. Villages with zero acreages were not reported on the table

3

Chapter 3

Studying the dynamics of technologies adoption using a mixed methods approach: The adoption of improved maize seeds among smallholder farmers in Uganda

Chapter 3

Studying the dynamics of technologies adoption using a mixed methods approach: The adoption of improved maize seeds among smallholder farmers in Uganda

Abstract

Differences in GDP per capita between countries can to a large degree be explained by differences in the level of technology. We seek to understand the dynamics of the adoption process of improved seeds in Uganda. This study investigates dynamics of the adoption process of improved seeds in eastern and mid-western Uganda using three waves of survey data from a sample of over 1900 rural households. We used the double hurdle model to estimate the determinants of adoption and disadoption. Transition matrices were used to evaluate the changes of adoption status i.e. from adoption to disadoption and vice versa. We find evidence of gender, education, dependency ratio and resource endowments influence adoption decision making. Human and natural capital are important for deciding the acreage allocated to improved seeds. However, education of the household head does not affect the extent of adoption. Physical capital, in the form of oxen and total assets, are positively related to the size of area under improved maize. Disadoption is common, but less frequent after two consecutive years of adoption. This suggests that for a substantial share of our sample, adoption and disadoption are recurring actions. Female headed households and low asset value stimulates disadoption. Significant changes in crop husbandry management practices are key in improved maize varieties cultivation. There is need for policies that consider both adoption and continued use of improved maize varieties.

Keywords: Improved maize varieties. Adoption. Disadoption. Uganda

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3.1 Introduction

Differences in GDP per capita between countries can to a large degree be explained by differences in the level of technology (Foster & Rosenzweig, 2010). This suggests that diffusion of technologies is a key mechanism for low-income countries to catch up with high income countries, and that a better understanding of technology diffusion and adoption is crucial for understanding growth. Technology diffusion and adoption in African agriculture is of particular interest to enhance development in rural areas. Improved seeds are among the many available technologies and are considered important for increasing productivity, incomes and food security (Awotide, Awoyemi, et al., 2012; Becerril & Abdulai, 2010; Kassie et al., 2011), especially since land available for farming is decreasing due to population growth (Salami et al., 2010). Yet, despite their potential benefits, the usage of improved seeds is low among smallholder farmers, who dominate agricultural production in Africa (Mubangizi et al., 2012).

This paper builds on the increasing literature on technology adoption among African farmers by studying the dynamics of the adoption of improved maize in Uganda. Independent of whether fertilizers are used or not, farmers planting improved maize seeds obtain higher gross profits than farmers who plant local seeds (Mathenge et al., 2014; Okoboi, 2010). Yet rates of adoption are moderate with only 34% of maize farmers in Uganda buying improved seeds (Sheahan & Barrett, 2014). This is low even compared to the neighbouring country of Kenya, where over 50% of maize farmers use improved seed (Mathenge et al., 2014).

Earlier studies either implicitly or explicitly considered adoption as an irreversible decision: once farmers adopt a technology, they will not give it up. Hence, they have largely ignored adoption dynamics at the household level (Conley & Udry, 2010; Foster & Rosenzweig, 2010). More recently, technology adoption has been studied as a learning process involving awareness, try out and adoption (e.g., (Lambrecht et al., 2014)). Farmers may experiment with the new technology and reverse to an older technology if, for example, the expected benefits are not met. However, this literature still uses a limited adoption concept in which adoption is seen as a permanent progression in which old methods, materials and tools are replaced by improved ones.

Technology adoption is in fact a fluid, iterative, and context-specific process (Glover et al., 2016; Jansen & Vellema, 2011). Farmers may adopt a new technology alongside an older one where they allocate each a portion of their land. They may also adopt a technology for some time (beyond experimentation) and then revert, for example because the costs or benefits have changed over time (Moser & Barrett, 2006; Teshome et al., 2012). There is a growing literature recognizing this through studying the continuation and discontinuation of the use of agricultural technologies at the household level (Bizoza, 2014; Moser & Barrett, 2003, 2006; Neill & Lee, 2001; Sanou et al., 2017; Tura et al., 2010; Wakeyo & Gardebroek, 2015). Due to the limited availability of panel data for developing countries, most of these studies have used cross-sectional data. These data provide a snapshot of the adoption process and result in biased and inconsistent coefficients of the determinants of adoption (Besley & Case, 1993). Examples of exceptions are Moser and Barrett (2006), who construct a pseudo-panel through recall and Sanou et al. (2017) and Wakeyo and Gardebroek (2015) who use panel data. Another limitation of many adoption studies is that they focus on adoption as a dichotomous variable and do not look at the scale or degree of adoption.

Building on the existing studies, we seek to understand the dynamics of the adoption process of improved seeds in Uganda. We answer two research questions; 1) What are the adoption dynamics for improved maize? and; 2) What are the determinants and motivations of adoption/disadoption decisions? To answer these questions, we use panel data from 1953 farmers in Eastern and Mid-Western Uganda collected between 2013 and 2016, complemented with in depth interviews and focus discussion groups from 2017. Our main contribution is that we do so using a multidisciplinary approach combining economics/sociology and quantitative/qualitative methods. We show that mixed methods research helps to provide richer insights in adoption decisions (Giller et al., 2011; Jefferson et al., 2014; Starr, 2014).

The structure of the paper is as follows. Section 2 presents the theoretical framework, which combines economic farm household model theory with sociological insights in agricultural innovation. Section 3 presents the context of maize production in Uganda, and Section 4 the data and methodology. Section 5 presents the results of the empirical analysis. By starting with the standard static econometric approach to studying adoption, extending this to a dynamic approach using panel data and finally adding insights from qualitative analysis, we show the added value of using a broad, dynamic perspective and mixing methods. Section 6 concludes.

3.2 Theoretical framework

The introduction of improved seeds implies much more than just buying more expensive seeds and harvesting higher yields. As Leeuwis (2013) indicates, a change 'never comes alone'. Farming is a complex system and changes in one domain (planting) will affect other domains (e.g. pest management, labour organization, weeding, storage). Adoption of improved seeds would thus result in a series of changes in crop management that the farmer has to perceive positively to engage in the adoption process (Glover et al., 2016). Put differently, the improved seed is the technical dimension of a larger innovation that also includes novel or changed social arrangements, both in terms of potential linkages to agro-dealers and extension workers as well as the internal organisation of labour in the households. This multidimensional character of innovations is important to consider when studying adoption (Leeuwis, 2013).

Each farm household is unique and has their own motivation and constraints in the adoption process. This can be illustrated using the non-separable farm household model (Taylor & Adelman, 2003). In this model, the household simultaneously acts as a producer and consumer to maximise utility subject to constraints such as land, labour, production technologies and market access. The household compares the expected utility of the different activities and technologies known and accessible to them and choses the combination that yields the highest utility. Technology adoption is thus conditional on the household's awareness and knowledge of the technology, the availability and affordability of the technology, and the contribution of the technology to household objectives conditional on market access and resource endowment.

Farm households can obtain information on new technologies from formal channels like extension services and mass media, but also from agro-dealers or other commercial agents and from neighbours and family. Finally, they can experiment themselves (Anderson & Feder, 2007). Effective extension requires more than just communicating standard messages to farmers. Extension workers must be able to adapt these to the complex situation that individual farmers face. Duflo et al. (2008), for example, found that while fertilizer can be very profitable when used correctly in Kenya, official recommendations are not adapted to many farmers, making it difficult for them to use fertilizers successfully.

To be able to adopt an innovation, the required inputs, such as seeds, fertilizers, and equipment - the technical dimension of the innovation, should be available and affordable to farmers. This requires adequate social relations. Limited market development may hinder timely availability of inputs in local markets. Agro-dealers are often far away or have limited stocks, and strong seasonality of activities hinders the development of labour markets forcing farmers to rely largely on family labour. In addition, farmers may be constrained in purchasing variable inputs due to the poor development of rural financial markets. In most developing countries, the development of these markets is severely limited due to for example informational asymmetries, high transaction costs and covariate demands, limiting the possibilities of smallholders to borrow and save. Also, procrastination in combination with overestimated patience may prevent farmers from saving even small amounts for profitable investments (Duflo et al., 2011).

When a known innovation is accessible and affordable to a farmer, they will weigh the expected utility of (continued) adoption against its alternatives. The utility of adoption depends on the contribution of the technology to the household's objectives related to, most importantly, the level and stability of income and food security. Given their importance for income, (changes in) output prices for agricultural produce play a key factor in the (dis)adoption of technologies (Kijima et al., 2011). Risk can hinder adoption when returns are uncertain due to either lack of sufficient knowledge or vulnerability to pests and diseases or weather and price fluctuations. Food security motivations are important in settings with imperfect food markets where producing one's own food may be more beneficial than producing for maximum income and subsequently buy food in the market. New technologies may then not or only to a limited extent be adopted because they don't fit the family's food preferences.

Based on the above, we can conclude that all farmers are not equally likely to adopt new technologies. All three core conditions for adoption –knowledge, availability and affordability, and utility, depend on the characteristics of the household and their farm. Key factors of interest are farmer and household characteristics, resource endowments, and the location in terms of market access and agro-ecological conditions.

Relevant farmer and household characteristics are age, education, gender, family composition, religion, and ethnicity. Age and education affect the farmers' access to, and capability of processing information related to new technologies and their willingness and ability to experiment. On the other hand, they may also affect the opportunity cost of family labour on the farm through their effect of access to off-farm employment. Gender is associated with access to information, access to markets, and preferences – that is the weighing of different objectives to determine utility. Extension agencies often target male farmers, and female farmers may have lower bargaining power towards traders and agro-dealers, thus buying and selling at less favourable conditions. In addition, women have been shown to have larger preferences for food than men, which may affect the production pattern in a setting with incomplete food markets (Duflo & Udry, 2004; Quisumbing, 1996). Similarly, family composition, religion, and ethnicity can be related to the utility of adoption. Family composition determines food requirements and preferences for age-specific goods and services, such as school fees. Religion and ethnicity may affect food habits and food taboos as well as other consumption habits and preferences.

Resource endowment affects adoption through various mechanisms. More resources mean more possibilities for small-scale farmers to experiment with new technologies without compromising normal production, thus generating tailor-made information on the costs and benefits of new technologies (De Janvry et al., 2011). When markets are imperfect, the availability of the required inputs for a specific technology largely depends on the household's own resources. Ample family labour may prevent labour shortages during peak seasons. In contrast, land can serve as collateral thus improving access to credit for financing purchased inputs. However, with poorly developed financial markets, this mechanism may not be effective. Households then need to rely on their own savings. The utility of different technologies is also a function of resource endowments. Technology adoption may be more profitable on larger farms due to economies of scale related to for example fixed costs of adoption –such as acquiring skills and knowledge, and logistics of trade –larger quantities of produce often imply higher prices (Collier & Dercon, 2014). In addition, possible trade-offs between higher incomes and less own food production are less likely to constrain technology adoption on larger farms. On the other hand, labour-intensive technologies will be more profitable on farms with ample family labour, which requires less supervision and has lower opportunity costs when off-farm employment opportunities are limited. Finally, the quality of land has an indeterminate effect on the use of agricultural technologies through its effects on expected returns (Carletto et al., 2007).

Location is a major determinant of agricultural production and thus technology adoption. Relevant technology information is not equally available in all places. Official recommendations for fertilizer use are often based on trials on research stations and may not match the situation in farmer fields farther away (Duflo et al., 2008). In addition, extension officers do not equally cover all areas. Relatedly, the availability of inputs differs depending on access to markets. Even if inputs can be purchased, distance to the market and agro-dealers reflects the transaction cost and opportunity cost associated with buying inputs and selling produce (Feder et al., 1985). Higher transaction costs imply lower incomes from input-intensive technologies. In addition, adoption patterns may differ in regions with different agro-ecological conditions (Amare et al., 2012; Asfaw et al., 2012; Shiferaw et al., 2014), as the level and variability of yields depend critically on the biological environment. In regions with ample opportunities for off-farm employment, the opportunity costs of family labour will be higher while cash-constraints may be lowered, constraining the adoption of labour-intensive technologies and stimulating the adoption of labour-saving technologies (see, e.g. (Davis et al., 2009) (Mathenge et al., 2015) (Amsalu & De Graaff, 2007; Tura et al., 2010)).

3.3 Maize production and the adoption of improved seeds in Uganda

Maize is one of Uganda's major staple crops. It is grown widely among smallholder farmers and is one of the strategic and priority crops under the National Agricultural Sector Strategic Plan (NASSP) of the national government (MAAIF, 2015). Maize is grown as a food crop as well as a cash crop. As land is scarce, farmers find it difficult to set aside land for investing in permanent cash crops such as coffee, tea or coca. In addition, dual purpose crops like maize can help improve farmers' food security in a risky environment with limited market development. Uganda has two growing seasons for maize in almost all the agro-ecological regions.

Farmers cultivate both improved and local maize varieties. Improved maize varieties include hybrids and Open Pollinated Varieties (OPVs). The latter are more popular than hybrids -about 90 percent of the area under improved maize seed is planted with OPVs in Uganda (Mastenbroek & Ntare, 2016). The main input is family labour. Most labour is required during the peak seasons of planting, weeding and harvesting. For land preparation and planting, some farmers use tractors and oxen ploughs, while others use hand implements such as hoes. Manual weeding is generally done two to three times in a season, but some farmers prefer the use of herbicides to minimise labour costs. Harvesting is done manually while shelling is done either manually or mechanically depending on the size of the harvest. Chemical fertilizers are used by only 8 percent of Ugandan farmers (Barungi et al., 2015).

Farmers get information on new varieties from seed companies, fellow farmers, research institutes, radio, the government institute National Agricultural Advisory Services (NAADS), non-governmental organisations (NGOs) and Community Based Organisations (CBOs) (Barungi et al., 2015). The information is provided to farmers through training, demonstration trials/plots, mass media, farmer field days, farmer exchange visits, farm visits among others.

Accessibility of improved seed is constrained by a weak seed supply system and a poor road network. The National Agricultural Research Organisation (NARO) is responsible for research on and production of new improved varieties. The improved seeds are then sold to seed companies who multiply, distribute and market them directly or through agro-dealers. Both agro-dealers and seed companies are located in major towns or trade centres that are far from many farming villages. In addition, counterfeit seeds of low quality are no exception in the market (Bold et al., 2017). These seeds are no different from local seed and have a low germination rate and low yields. To counteract the counterfeit problem, Feed the Future has launched an electronic verification system in collaboration with the Uganda National Bureau of Standards and the Ministry of Agriculture Animal and Fisheries in 2015 (TETRATECH, 2016). The system enables farmers to verify if the input is genuine and up to date by sending a code on the scratch off label to seed company through SMS. However, not all seed companies have been integrated into the system, and farmers have limited knowledge about it.

In general, farmers consider attributes such as yields, profitability, grain size, grain colour, taste, tolerance for pests and diseases, and seed costs when selecting varieties to plant. For consumption, farmers prefer maize varieties that are sweet and can be stored for a long period. For sale, farmers prefer maize varieties that have high yields, are tolerant to pests and diseases, and have a short maturity period. There is no differentiation of maize grains in the market – maize with preferred traits does not get a premium (Mastenbroek & Ntare, 2016).

With proper input application and crop management, hybrids have expected yields of about 7-9 tonnes/acre, OPVs 4-6 tonnes/hectare, and local varieties 2 tonnes/hectare. Even without chemical fertilisers, good quality improved varieties have higher yields than local varieties, which translate into higher profits (Okoboi, 2010). However, farmers incur higher expenditures because of high seed cost. Hybrid seeds are the most expensive at 4000-6000UGX/kg, followed by OPVs at 2500-3000UGX/kg; Least expensive is local maize seed at 300-600UGX/kg in 2015 (FAO, 2017a). In addition, while local seeds can be recycled easily, farmers need to purchase new improved seeds regularly to maintain high yields. One-time recycled hybrids generally produce 32 percent less than the first generation, and one-time recycled OPVs 5 percent (Pixley & Banziger, 2001). Reductions are higher in following generations. When seeds are recycled over a long period of time, yields are comparable with local seeds (Yamano et al., 2011). Still, farmers recycle both hybrids and OPVs. When it then becomes impossible for them to identify the varieties using original names, they start calling them local varieties.

3.4 Data and methodology

3.4.1 Data

The study was conducted in four maize-growing districts in Uganda: Tororo and Iganga districts in Eastern Uganda and Masindi and Hoima districts in Mid-western Uganda. From each district, four sub-counties were selected. Villages were randomly selected from the sub-counties totalling to 14 villages in each sub-county. Finally, 10 households were randomly selected from each village for participation in the survey.

Data were collected from these same households for three years in a row (2013/14, 2014/15 and 2015/16). The number of households reached during the first year and second year were 2,133. 1,953 were interviewed in both years. During the third-year data collection (2015/16), 2,035 households were interviewed and among them were all 1,953 households interviewed in both earlier rounds. Some households were not reached during the first-, second- and third-year surveys due to refusals, unavailability, or dissolution of the household. The overall attrition rate from baseline was 8.4 percent; 3.8 percent in 2014/15 and 4.6 percent in 2015/16. The full panel data covers six growing seasons, two for each year. Data were collected after the second season.

The survey included questions on farm and household characteristics, such as land size, other assets, household size, gender, age and education of the household head, and distances to the extension service, agro-dealers and the produce market. Data on crop production were collected at plot level for each season. We expected the farmers to recall most of the crops they planted in both seasons, as there was little or no crop production recording. Most farmers indeed experienced no difficulties in recalling because they plant almost the same crops in each season. For maize and selected other crops, farmers were asked for the type of seed used, originally distinguishing four categories: purchased hybrid seeds, purchased OPVs, recycled seeds, and local seeds. During field testing, however, farmers appeared unable to distinguish between hybrids and OPVs. Contrary to local seeds, hybrids and OPVs are certified and packaged. Farmers were able to tell whether they used packaged maize seed sold in agro-shops or seed companies or unpackaged maize seeds from the local market. However, many could not tell which specific packaged seed they used. We therefore do not distinguish between hybrids and OPVs and classified both as improved seeds.

In addition to the surveys, we carried out in-depth interviews/case studies and focus group discussions (FGDs) in 2017. We conducted 33 case-studies (in-depth farmer interviews) spread out over 16 villages. Based on the survey data, we purposively selected sub-samples of farmers based on their adoption status: those who planted the improved seeds and those who did not. In each of the 16 villages, we organized a FGD with farmers. We also interviewed 17 key informants, which we purposively selected putting into consideration the role they play in the agricultural sector, and especially in maize farming and the distribution of information and seeds to farmers. Key informants included input suppliers (agro-vet shops), ministry of agriculture officials at district level and agricultural extension officers in the sub-county level. The first author conducted the interviews and led the discussions with the aid of a local research assistant from each district. Data were recorded in audio and detailed notes.

For the case studies, we used a technography approach to understand how resources are mobilised in the use of improved seeds (Jansen & Vellema, 2011). The improved-seeds group provides information-rich cases (Patton, 2001) for changes that occur when the farmers use improved seeds. The local-seeds group provides detailed information on traditional maize farming. The case studies also provide insight in factors that may hinder the uptake of improved seed, reasons for disadopting, and how farmers managed their crops depending on the variety planted. Focus group discussions (FGDs) were conducted to explore farmers' perceptions about improved seed, their use of improved seed and constraints faced with respect to use of improved seed. Key informants were interviewed regarding adoption in the area, reasons and constraints of adoption.

3.4.2 Methodology

We used a sequential mixed method approach, adding data in a stepwise procedure. First, we start with the relatively conventional economic adoption analysis using cross sectional data. Second, we extend our data to the three-year panel. The panel data gives detailed information on (dis)adoption dynamics and on which farmers (dis)adopt. Third, we add the qualitative data. Triangulation of key informants, FGDs and farmer interviews provided the social and contextual issues that come along with adoption decisions. These issues include the unpacking of the crop husbandry changes, constraints faced when using improved seeds, and reasons for (dis)adoption.

The first step involves assessing the determinants of adoption, using a double hurdle model as originally formulated by Cragg (1971). Dependent variables are a dichotomous and a continuous variable of adoption. The model assumes that households must pass two hurdles before a positive level of an outcome is observed. The first hurdle is the decision to adopt (positive or zero), and the second hurdle is the decision on the amount and proportion of maize land to allocate to the improved seeds. The double hurdle model is formalized as follows:

$D = 1 \; if \; x_i\alpha + v_i > 0$ First hurdle (Adoption decision) 3.1

$\text{D} = 0$ otherwise

$y_i^* = x_i\beta + u_i$ Second hurdle (Extent of adoption) 3.2

$y_i = y_i^* \; if \; D = 1 \; \; and \; y_i^* > 0$ 3.3

$y_i = 0$ otherwise

where D is the latent variable describing the household's decision to adopt improved seeds (1 if adopted and 0 if not), y_i^* is the latent variable describing the household's decision on the extent of adoption (acreage/proportion allocated to improved seed), and y_i is the observed extent of adoption for farmer i. x_i is a vector of explanatory variables explaining the adoption decisions, v_i and u_i are the error terms, which are robust to heteroscedasticity. In the model, the determinants of adoption and the extent of adoption are the same although the degree to which they influence the two decisions may be different. This follows from the non-separable household model, which specifies that all household decisions are taken simultaneously. The model is estimated using maximum likelihood procedures.

In the second step, we introduce the two other waves of the panel to gain insight in the adoption dynamics. We analyse the dynamics of adoption using transition matrices to determine the probability of adopting/disadopting depending on adoption or non-adoption in the previous year(s). As this analysis clearly shows that the adoption process is not a unidirectional spread of the innovation from early to late adopters, we then analyse the determinants of both adoption and disadoption using regression analysis. We do not use standard panel data methods (a random effects version of the double hurdle model) for two reasons. First, most of the determinants as specified in Section 2 -farmer and household characteristics, resource endowments, and the location in terms of market access and agro-ecological conditions, are relatively stable over time. Between-year dynamics are subtle and difficult to estimate quantitatively. Second, the degree in which factors determine adoption and disadoption is not necessarily the same. Hence, we classify farmers into three partly overlapping groups: non-adopters; adopters; and disadopters. We consider farmers adopters if they adopted in any of the three survey years. Similarly, someone is a disadopter if they adopt in year 1 and/or 2, but not in the subsequent year. The extent of adoption is then the average area under improved maize over the three years and, alternatively, the average share of maize land cultivated with improved seeds. We then re-apply the static double hurdle model described above to study adoption decisions and use a probit model to study disadoption. Independent variables are taken from the baseline.

In third step we employ the qualitative data. We use thematic analysis to examine text data using codes to retrieve important information from the data collected. Quotes from the respondents were used to represent the themes in the data (Rubin & Rubin, 2011). Data were analysed using four themes:

- (Differences in) crop management in improved and local maize varieties
- Reasons for adopting/not adopting improved seeds
- Reasons for disadopting improved seeds
- Constraints and challenges faced when using improved/local maize seed

3.5 Empirical analysis

3.5.1 Econometric analysis with cross sectional data

The pattern of adoption depends on the assumptions made on recycled seeds. Seeds that farmers have classified as recycled could be considered improved or local depending on the type of seed and the number of seasons since purchase. The largest share of improved seeds used by farmers in the study region are OPVs. As indicated before, these can be recycled while keeping most of their characteristics, but only for a limited number of times. Here we assume that seeds can be recycled for three seasons. If they are recycled more often, the beneficial properties will wear off and we consider them local seeds.

As shown in Table 3.1, 45 percent of farmers cultivated improved maize. They cultivated 2.59 acres on average, which was almost 90 percent of their total maize area and about half of their land owned. For the full sample, just over 40 percent of all maize cultivated was improved. Adopters are somewhat better educated, more likely to be male, and wealthier on average, and adoption rates were lowest in Hoima. The regressions results presented below reflect these differences.

Table 3.1: Descriptive statistics of the respondents (2015/16)

	Full sample	Non-adopters	Adopters	T-test
Cultivation of improved maize				
Area under improved maize (acres)	1.17	0	2.59	
	(2.28)	(0)	(2.81)	
Proportion of improved maize with	0.41	0	0.89	
improved seeds	(0.47)	(0)	(0.21)	
Farmer and household characteristics				
Age of the household head (years)	48.92	50.8	46.64	0.000(***)
	(14.43)	(15.03)	(13.33)	
Gender of the household head (1=Male,	0.87	0.83	0.92	0.000(***)
0=Female)	(0.34)	(0.38)	(0.28)	
Education (1=above primary education,	0.47	0.42	0.52	0.000(***)
otherwise=0)	(0.50)	(0.49)	(0.50)	
Dependency Ratio	50.39	50.25	50.56	0.741
	(20.15)	(20.98)	(19.1)	
Resource endowment				
Land owned (acres)	4.44	4.05	4.92	0.071(*)
	(8.01)	(8.86)	(6.82)	
Number of adults in the household (15-60	3.43	3.30	3.58	0.001(***)
years)	(1.86)	(1.84)	(1.87)	
Whether the household owned an Oxen	0.12	0.10	0.15	0.000(***)
(1=Yes, 0=No)	(0.32)	(0.29)	(0.36)	
Asset value (UGX; 1,000,000)	1.77	1.49	2.11	0.000(***)
	(3.32)	(2.62)	(3.98)	
Tropical Livestock Unit	1.46	1.20	1.79	0.002(***)
	(4.14)	(2.50)	(5.49)	
Location				
Distance to the nearest extension office	6.21	6.21	6.21	0.982
(km)	(5.56)	(5.29)	(5.87)	
Distance to the nearest agro-dealer (km)	6.70	6.40	7.07	0.022(**)
	(6.34)	(5.98)	(6.74)	
Distance to the nearest produce market (km)	5.70	5.56	5.88	0.276
	(6.35)	(6.02)	(6.73)	
District; Hoima=1, otherwise=0	0.25	0.38	0.10	0.000(***)
	(0.43)	(0.49)	(0.3)	
District; Masindi=1, otherwise=0	0.22	0.13	0.33	0.000(***)
	(0.41)	(0.33)	(0.47)	
District; Tororo=1, otherwise=0	0.27	0.24	0.30	0.003(***)
	(0.44)	(0.43)	(0.46)	
District; Iganga=1, otherwise=0	0.26	0.25	0.27	0.396
	(0.44)	(0.44)	(0.44)	
N	1953	1073	880	

Standard deviation in parenthesis. Tropical Livestock Units are livestock numbers converted to a common unit. Conversion factors are: exotic cattle=1, indigenous cattle = 0.7, sheep = 0.1, exotic goats = 0.15, indigenous goats=0.1, pigs = 0.2, improved chicken = 0.015, indigenous chicken 0.01, pigeons 0.005, Turkey and ducks 0.03, rabbits 0.02

Considering the dichotomous adoption decision, we find that men were more likely to adopt than women (Table 3.2). They may have had better access to technology. Farmers who had education above primary school were more likely to adopt the improved maize varieties. This suggests that general education was important for understanding the technology, being able to access it, and benefit from it through interactions with actors in input and output markets. Also other studies find that well-educated household heads are more likely to adopt (Adesina & Zinnah, 1993; Langyintuo & Mungoma, 2008). Interestingly, a higher dependency ratio implied a higher probability of adoption. Possible explanations could be a higher need for cash income from the farm, increased labour availability, or lower needs for maize from own consumption.

Resource endowments were positively linked to adoption. We find positive effects for both land and labour. These results are in line with the literature (Awotide, Diagne, et al., 2012; Doss, 2006; Kassie et al., 2011; Langyintuo & Mungoma, 2008). The effect of land decreased slightly with farm size. Possibly, improved seeds were sold in minimum package sizes, which could hinder adoption on a very small scale. Also, the preference to grow local maize for own consumption could limit adoption on small farms. Improved seeds may require more intensive crop management and would thus be favoured by the availability of additional family labour. We find limited effect of the location variables. Adoption rates and areas were lowest in Hoima and highest in Masindi, but we find no effects of distance to markets and extension.

The double hurdle model allows moving beyond adoption as a yes/no decision and instead looking at the extent of adoption. We find similar results for acreage as for adoption: both human and natural capital were important. In addition, we find that physical capital, in the form of oxen and total assets, are positively related to the size of area under improved maize. These may be linked to the availability of financial capital need to purchase seeds in larger quantities. Interestingly, the gender of the household head only affected adoption and not the extent of adoption. This suggests access was the main problem. Perhaps surprisingly, we find few significant coefficients for the regression of the proportion of maize land allocated to improved seeds. This suggests that farmers did not replace local maize with improved maize but instead cultivated more land under maize to the same extent under local maize. This latter result is puzzling.

Table 3.2: Double hurdle results: Factors affecting the adoption decision, acreage and proportion of maize land under improved seeds (2015/16)

	Adoption (yes/no)	Extent of adoption	
		Acreage of land allocated to improved maize	Proportion of maize land allocated to improved seeds
Farmer and household characteristics			
Age of the household head (years)	-0.005	0.060*	-0.001
	(0.015)	(0.035)	(0.004)
Age of the household head squared	-0.0001	-0.001**	-0.000001
	(0.0001)	(0.0003)	(0.00003)
Gender of the household head (1=Male, 0=Female)	0.329***	0.077	0.006
	(0.100)	(0.256)	(0.026)
Education (1=above primary education, otherwise=0)	0.165**	0.355**	0.017
	(0.065)	(0.164)	(0.015)
Dependency Ratio	0.004**	0.009**	-0.0004
	(0.002)	(0.004)	(0.0004)
Resource endowment			
Land owned (acres)	0.060***	0.115***	0.004**
	(0.011)	(0.041)	(0.002)
Land owned squared	-0.001***	-0.00005	-0.00003
	(0.0002)	(0.001)	(0.00002)
Number of adults in the household (15-60 years)	0.046**	0.192***	-0.0003
	(0.023)	(0.065)	(0.005)
Whether the household owned an Oxen: Yes=1, No=0	-0.026	0.503*	-0.020
	(0.105)	(0.271)	(0.023)
Asset value (UGX; 1,000,000)	0.022	0.107**	-0.0001
	(0.014)	(0.054)	(0.001)
Tropical Livestock Unit	-0.001	0.012	0.001
	(0.01)	(0.035)	(0.001)
Location			
Distance to the nearest extension office (km)	0.001	-0.018	-0.003
	(0.007)	(0.022)	(0.002)

Distance to the nearest agro-dealer (km)	0.008	0.026*	0.0001
	(0.005)	(0.014)	(0.001)
Distance to the nearest produce market (km)	0.001	0.014	0.0001
	(0.005)	(0.014)	(0.001)
District; Masindi=1, otherwise=0	1.530***	1.504***	0.019
	(0.099)	(0.365)	(0.019)
District; Tororo=1, otherwise=0	1.226***	-0.071	-0.077***
	(0.102)	(0.346)	(0.024)
District; Iganga=1, otherwise=0	1.053***	0.402	-0.073***
	(0.105)	(0.349)	(0.025)
Constant	-1.651***	-1.299	0.996***
	(0.412)	(1.053)	(0.095)
N	1953	880	880
Pseudo R2	0.1595	0.2506	0.0604

Standard errors in parentheses. *** p=0 .01 ** p=0.05 * p=0.1

3.5.2 Econometric analysis using panel data

3.5.2.1 Dynamics of adoption

The availability of panel data allows us to study the dynamics of adoption. Parallel to our reasoning above, what we consider adoption and disadoption depends on the assumptions made on recycled seeds. We now use two different assumptions. First, we take the position that OPVs can be recycled for one season only. Second, we use the less conservative assumption that seeds can be recycled for three seasons. Both definitions imply additional assumptions due to missing data. For analysis, we do have the required information on seed purchases in the second season of 2013/2014 -the year before our first survey. We therefore classify all recycled seeds in the first season of 2014/15 as local. This seems a realistic assumption, as generally farmers purchase improved seeds only for the first season and not for the second, though this will imply an underestimation of adoption in the first year. The associated transition matrices are presented in Table 3.3A (one season of recycling) and Table 3.3B (three seasons of recycling).

Looking at panel A and B of Table 3.3A, we see that adoption rates increased over the years, but with decreasing steps, from 25 percent in 2014/15 to 34 percent in 2015/16 and 37 percent in the 2016/17. In both the second and the third year of the panel, almost 26 percent of farmers who did not use improved seeds in the previous year adopted them in the current year. In addition, around 41 percent of farmers who did use approved seeds in the previous year, disadopted in the current year. These numbers are strikingly similar between the two years. If they would remain stable in the following years; this would result in an equilibrium share of about 40 percent of farmers using improved seeds, which is close to the third-year user rates.

Looking at the dynamics in panel C, we see that 43.5 percent of farmers did not adopt improved seeds at all, while 11.4 percent used improved seeds in all three years. This implies that 45.1 percent of households switched between use and non-use at some point. The dynamics within this group are diverse. Disadoption was common, but less frequent after two consecutive years of adoption: in the final year, 24.4 percent of two-time adopters disadopted, as compared to 55.5 percent of one-time adopters. Conversely, disadoption was often reversed as well: 48.5 percent of disadopters from the second year adopted again in year 3. This suggests that for a substantial share of our sample, adoption and disadoption are recurring actions.

Table 3.3A: Transition matrices of the use of improved seeds, one season recycling allowed (N=1953)

Panel A		2014/15 (% of farmers)		
2013/14		No	Yes	All
No		55.5(74.4)	19.1(25.6)	74.6(100)
Yes		10.3(40.6)	15.1(59.4)	25.4(100)
All		65.8	34.2	100
Panel B		2015/16 (% of farmers)		
2014/15		No	Yes	All
No		48.8(74.2)	17.0(25.8)	65.8(100)
Yes		14.2(41.5)	20.0(58.5)	34.2(100)
All		63.0	37.0	100
Panel C		2015/16 (% of farmers)		
2013/14	2014/15	No	Yes	All
No	No	**43.5** (78.4)	12.0 (21.6)	55.5(100)
No	Yes	10.5 (55.0)	8.6 (45.0)	19.1(100)
Yes	No	5.3 (51.5)	5.0 (48.5)	10.3(100)
Yes	Yes	3.7 (24.4)	**11.4** (75.6)	15.1(100)
All	All	63.0	37.0	100

Notes: Row percentages in parentheses; **Bold** means stay in the same category throughout the three years

Table 3.3B: Transition matrices of the use of improved seeds, three seasons recycling allowed (N=1953)

Panel A		2014/15 (% of farmers)		
2013/14		No	Yes	All
No		55.5(74.4)	19.1(25.6)	74.6(100)
Yes		4.8(18.9)	20.6(81.1)	25.5(100)
All		60.3	39.7	100.0
Panel B		2015/16 (% of farmers)		
2014/15		No	Yes	All
No		45.9(76.1)	14.4(23.9)	60.3(100)
Yes		9.1(22.8)	30.7(78.1)	39.8 (100)
All		54.9	45.1	100.0
Panel C		2015/16 (% of farmers)		
2013/14	2014/15	No	Yes	All
No	No	**43.5** (78.4)	12.0 (21.6)	55.5(100)
No	Yes	5.8 (30.6)	13.3 (69.4)	19.1(100)
Yes	No	2.4 (50.0)	2.4 (50.0)	4.8(100)
Yes	Yes	3.2 (15.6)	**17.4** (84.4)	20.6(100)
All	All	54.9	45.1	100

Notes: Row percentages in parentheses; **Bold** means stay in the same category throughout the three years

Taking a less conservative position and assuming that OPVs can be recycled for 3 seasons without losing too much of their strength, we get a slightly different picture (Table 3.3B). Still, about 20 percent of non-adopters adopt improved seeds in the subsequent years. However, logically disadoption decreases: about 80 percent of previous adopters continues to adopt in the subsequent year, compared to 76 percent using the more conservative definition of improved seeds. This shows that part of the adoption dynamics observed on table 3.3B is the result of farmers recycling seeds slightly longer than the official recommendations. We now find that 17 percent of farmers used improved seeds throughout the research periods and 39 percent used improved seeds at least once but not every year.

3.5.2.2 Factors influencing technology adoption and disadoption

These dynamic imply that we can classify farmers into three partially overlapping groups: non-adopters, who did not plant improved seeds at any time within the three years; adopters, who planted the improved seeds at least once in the three years; and disadopters, who adopted and disadopted at least once during the three years. Adopters comprise 57 percent of all farmers (Table 3.4), which is substantially higher than the 41 percent adopters in the endline. Corrected for households adopting only in the final survey year, 31 percent of adopters disadopted again afterwards.

The baseline characteristics of the full sample and the three groups are presented in Table 3.4. Compared to Table 3.2, which presents the characteristics of adopters at endline, the adoption rate are lower. This is logical, as adoption increased over the years, and we give three-year averages of adopters including the years in which they did not adopt. Like for the endline data, adopters were more likely to be educated and male, and they had more resources on average. Interestingly, this was less the case for the subgroup of disadopters.

We can now analyse the determinants of adoption considering the adopters over three years (Table 3.5) as compared to the adopters at the endline only (Table 3.2). The results are quite similar, though some variables that were significant in the endline regression are not in the overall regression and vice versa. The general story that educated farmers with more resources were more likely to adopt and adopt to a larger extent still holds. Interestingly, we now do find that not only the acreage of improved maize was affected but also the share of maize under improved seeds. This suggests that the area under improved maize increased more than the area under local maize, as expected. We no longer find a significant positive effect of being male on adoption. This suggests that women were just as likely to adopt at some point in a longer period but were less likely to sustain adoption over longer periods. We assess this directly by looking at the regression for disadoption.

Table 3.4: Descriptive Statistics of the Respondents

	Full sample	Non-adopters	Adopters[2]	Disadopters[3]
Maize acreage (three-year averages)				
Area under improved maize (acres)	0.95	0	1.69***	0.84***
	(1.80)	(0)	(2.13)	(0.87)
Proportion of maize area sown with improved seeds	0.32	0	0.57***	0.39***
	(0.35)	(0)	(0.28)	(0.17)
Farmer and household characteristics (baseline)				
Age of the household head (years)	47.47	50.08	45.46***	46.09
	(0.33)	(0.53)	(0.42)	(0.86)
Gender of the household head (1=Male, 0=Female)	0.89	0.85	0.91***	0.88***
	(0.01)	(0.01)	(0.01)	(0.02)
Education (1=above primary education; otherwise=0)	0.48	0.41	0.53***	0.50
	(0.01)	(0.02)	(0.02)	(0.03)
Dependency Ratio	51.52	51.48	51.55	50.66
	(0.46)	(0.73)	(0.60)	(1.29)
Resource endowment (baseline)				
Land owned (acres)	5.05	4.68	5.33**	4.53
	(0.29)	(0.38)	(0.42)	(0.38)
Number of adults in the household (15-60 years)	3.41	3.25	3.53***	3.49
	(0.04)	(0.06)	(0.06)	(0.12)
Whether the household owned an Oxen (1=Yes, 0=No)	0.10	0.07	0.12***	0.11
	(0.01)	(0.01)	(0.01)	(0.02)
Asset value (UGX; 1,000,000)	2.17	1.82	2.44***	1.97***
	(0.09)	(0.12)	(0.14)	(0.18)
Tropical Livestock Unit	1.25	1.12	1.35**	1.17
	(0.06)	(0.08)	(0.09)	(0.15)
Location				
Distance to the nearest extension office (km)	6.00	5.98	6.02	6.13
	(0.12)	(0.19)	(0.17)	(0.33)
Distance to the nearest agro-dealer (km)	8.00	7.94	8.04	7.76
	(0.17)	(0.24)	(0.23)	(0.45)
Distance to the nearest produce market (km)	7.7	7.48	7.80	8.0
	(0.18)	(0.26)	(0.26)	(0.54)
District; Hoima=1, otherwise=0	0.25	0.4	0.14***	0.25***
	(0.01)	(0.02)	(0.01)	(0.03)
District; Masindi=1, otherwise=0	0.22	0.12	0.30***	0.21***
	(0.01)	(0.01)	(0.01)	(0.02)
District; Tororo=1, otherwise=0	0.27	0.23	0.29	0.27
	(0.01)	(0.01)	(0.01)	(0.03)
District; Iganga=1, otherwise=0	0.26	0.25	0.27	0.27
	(0.01)	(0.02)	(0.01)	(0.03)
N	1953	849	1104	271

Standard errors in parenthesis. Tropical Livestock Units are livestock numbers converted to a common unit. Conversion factors are exotic cattle=1, indigenous cattle = 0.7, sheep = 0.1, exotic goats = 0.15, indigenous goats=0.1, pigs = 0.2, improved chicken = 0.015, indigenous chicken 0.01, pigeons 0.005, Turkey and ducks 0.03, rabbits 0.02

[2] T-test with non-adopters and adopters (adopters row)
[3] T-test with adopters and disadopters (disadopters row)

Table 3.5: Double hurdle results: Factors Affecting Adoption Decision, Acreage and Proportion of Land under Improved Maize Seed (all the three years)

	Adoption (yes/no)	Extent of adoption	
		Mean acreage of land allocated to improved maize	Mean proportion of land allocated to improved maize
Farmer and household characteristics			
Age of the household head (years)	-0.024*	0.014	0.002
	(0.014)	(0.02)	(0.004)
Age of the household head squared	0.0001	-0.0003*	-0.00004
	(0.0001)	(0.0001)	(0.00004)
Gender of the household head (1=Male, 0=Female)	0.163	0.106	0.037
	(0.100)	(0.183)	(0.032)
Education (1=above primary education; otherwise=0)	0.233***	0.070	0.046**
	(0.063)	(0.129)	(0.018)
Dependency Ratio	0.003*	0.003	-0.00007
	(0.002)	(0.003)	(0.0004)
Resource endowment			
Land owned (acres)	0.011*	0.078***	0.006***
	(0.01)	(0.023)	(0.001)
Land owned squared	-0.00002	-0.0002***	-0.00001***
	(0.00002)	(0.0001)	(0.00003)
Number of adults in the household (15-60 years)	0.065***	0.077*	0.001
	(0.020)	(0.042)	(0.005)
Whether the household owned an Oxen: Yes=1	0.146	0.421	0.004
	(0.119)	(0.28)	(0.031)
Asset value (UGX; 1,000,000)	0.028**	0.140*	0.005*
	(0.014)	(0.076)	(0.003)
Tropical Livestock Unit	-0.014	-0.031	-0.001
	(0.015)	(0.082)	(0.003)
Location			
Distance to the nearest extension office (km)	0.002	-0.003	-0.003
	(0.006)	(0.012)	(0.002)
Distance to the nearest agro-dealer (km)	0.002	0.0002	-0.0005
	(0.005)	(0.009)	(0.001)
Distance to the nearest produce market (km)	0.006	0.004	0.001
	(0.004)	(0.007)	(0.001)
District; Masindi=1, otherwise=0	1.312***	1.356***	0.278***
	(0.094)	(0.242)	(0.029)
District; Tororo=1, otherwise=0	0.976***	0.105	0.045
	(0.092)	(0.186)	(0.031)
District; Iganga=1, otherwise=0	0.784***	0.608***	0.068**
	(0.095)	(0.2)	(0.032)
Constant	-0.462	-0.083	0.381***
	(0.354)	(0.549)	(0.106)
N	1953	1104	1104
Pseudo R2	0.1291	0.2712	0.1857

Standard errors in parentheses. *** p=0 .01 ** p=0.05 * p=0.1

Chapter 3

Table 3.6: Disadoption Decision Probit Estimates

	Disadoption decision
Farmer and household characteristics	
Age of the household head (years)	0.005
	(0.007)
Age of the household head squared	-0.00003
	(0.00007)
Gender of the household head (1=Male, 0=Female)	-0.134**
	(0.065)
Education (1=above primary education; otherwise=0)	-0.039
	(0.033)
Dependency Ratio	-0.0008
	(0.001)
Resource endowment	
Land owned (acres)	-0.004
	(0.004)
Land owned squared	0.00004
	(0.0001)
Number of adults in the household (15-60 years)	-0.010
	(0.010)
Whether the household owned an Oxen: (1=Yes, 0=No)	0.058
	(0.059)
Asset value (UGX; 1,000,000)	-0.013**
	(0.006)
Tropical Livestock Unit (TLU)	-0.00004
	(0.008)
Location	
Distance to the nearest extension office (km)	0.004
	(0.003)
Distance to the nearest agro-dealer (km)	-0.003
	(0.003)
Distance to the nearest produce market (km)	0.001
	(0.002)
District; Masindi=1, otherwise=0	-0.366***
	(0.038)
District; Tororo=1, otherwise=0	-0.221***
	(0.041)
District; Iganga=1, otherwise=0	-0.221***
	(0.042)
N	870
Pseudo R2	0.0712

*** p=0 .01 ** p=0.05 * p=0.1. Standard errors in parentheses.

As shown in Table 3.6, female-headed households were indeed more likely to disadopt compared to male-headed households. This seems to suggest that women were not so much constrained in the purchase of seeds but perceived less benefits when using them. As explained before, improved maize is mainly produced for the market, which is male dominated. For own food production, a traditional women's domain, people generally prefer the sweeter local varieties. Alternatively, access to funds to purchase seeds may have fluctuated more for women than for men.

A low asset value was positively associated with disadoption, thus strengthening the negative effects of few assets on adoption. It thus seems that one-time adoption did not solve the financial barriers for improved seed use. However, we do not find similar effects for land ownership. Interestingly, the availability of family labour, an important determinant of adoption, had no significant impact on disadoption. Disadoption was more prominent in Hoima district, where adoption was already low.

3.5.3 Adding qualitative information.

The core findings from the quantitative analysis are thus that adoption was quite widespread, but by no means irreversible. In addition, adoption was never complete. Even when farmers planted improved maize, they still maintained a plot with local maize. Adoption levels differed between farmers depending on their characteristics. The more resources farmers had, the more likely they were to adopt and to adopt on a larger scale, and the less likely they were to disadopt. This held for labour as well as other resources. Below, we show how the qualitative information can help to understand the reasons behind each of these observed behaviours.

Adoption was widespread because farmers recognized several advantages of improved seeds over local seeds, many of which are related to the harvested grain. They indicated that improved seeds have higher yields, a higher weight, bigger grains. One farmer gave as an example that the grains from the hybrid varieties (Longe10H) weigh more than those of OPVs (Longe5) and that the local seeds weigh least. The improved maize varieties bear big cobs or two cobs per plant with many rows in a cob resulting in high yields. Grains from improved varieties were more marketable and preferred by the buyers because they had uniform bigger and whiter grains compared to local maize seed. Yet there was no difference in the price per bag. Farmers also mentioned a higher tolerance to several pests and diseases. This is in accordance with the literature, which indicates that some of the improved varieties are resistant to maize streak virus, grey leaf spot, and northern corn leaf blight (FAO, 2017a; Mabaya et al., 2018 (Revised 2019)). In addition, farmers mentioned that the germination rate for improved maize seed was high -for genuine seeds. Finally, the improved seed take a shorter time to mature such that one could get yields even when the rains are limited.

The high rates of disadoption were caused by disappointment with the technology as well as incapability to continue adoption. Farmers reported disadopting when a substantial part of the improved seed did not germinate, or the yields were no different from the local seeds. This likely reflects the use of counterfeit seeds, but not all farmers recognized it as such. Some farmers did not trust any improved seeds anymore, not even certified seeds from the agro-dealer store. These farmers could not differentiate between fake and genuine seeds because they are packaged in similar bags. Other farmers, could, however, recognize genuine seeds, as they were clean, of uniform size and had no broken grains. These farmers had generally used improved seeds for several years. As a second reason for disadoption, farmers mention a lack of funds to buy new improved seeds at the start of the season. One farmer stated: “At times I have no money to buy certified seed”. Another farmer reported that he bought certified seed in 2013 and keeps recycling despite decreasing yields because when a new season for planting approaches, he never has resources to purchase expensive seeds. This behaviour is consistent with a study in Kenya where farmers procrastinate to purchase inputs at a later date but then cannot do so due to lack of money (Duflo et al., 2011).

Farmers indicated they continue to grow local maize even when adopting improved seeds because they dislike using improved maize for own consumption. They mentioned that the improved varieties are not as sweet as local varieties when roasted or cooked. One of the farmers said that; “Longe 7H and Longe10H are not sweet; Longe7H has a watery texture when cooked”. Comparing the improved varieties, the Longe 5 and Longe 4 are relatively sweet and farmers prefer them for consumption compared to the other OPVs. Yet they prefer to eat local varieties the most because they are sweetest, and the flour is good for making posho (mixture of water and maize flour); when local varieties are boiled, the husk remains intact.

The explanation for the positive relation between resources and adoption seems obvious: Improved seeds are expensive and will therefore be easier to purchase for wealthier farmers. However, our in-depth interviews and FGDs indicate that this is not the only explanation. The use of improved seeds is risky. Plants from improved seeds do not have strong stems to withstand heavy rains, hailstorms and strong winds. Wealthier farmers can better deal with this increased risk. Perhaps more importantly, the seed innovation has various technical and social dimensions -as explained in Section 3.2, and the adoption of improved seeds implies substantial changes in the production system. We will show below that these changes better suit farmers with more financial and labour resources and some basic level of education.

Access to financial capital is not only important to enable seed purchase. Improved maize varieties, especially the hybrids, are more sensitive to stem borers. This caused many farmers to spray improved maize with pesticides. The tendency to spray improved maize increased after the introduction of fall armyworm in 2016, which has caused extensive and widespread damage, especially to improved maize varieties. Fertilizer use was, on the other hand, hardly affected by the introduction of improved varieties, as farmers perceived their soils as fertile. From the survey data, only 9.9% of farmers planting improved maize seeds and 8.6% of farmers planting recycled/local seeds used fertilisers. These low numbers are consistent with Barungi et al. (2015) and Sheahan and Barrett (2014).

Family labour is the key input in the maize production process besides land. Most of the maize cropping activities were split between the men and women of the household. The men carried out activities such as slashing, ploughing, planting, fertiliser and pesticide application and transporting. Women were involved in planting, weeding, harvesting, shelling, storing and drying. One farmer explained; “We do the planting together. The man digs the hole while the woman/children puts the seeds in the hole and covers it with soil.” Farmers used hired labour when family labour was not sufficiently available, especially during the peak periods of weeding and harvesting, but it was difficult to get hired labour during the on season because everyone is working on their own farm.

The improved seed system intensifies labour use in peak periods, thus increasing the importance of sufficient availability of family labour. Contrary to local varieties, improved varieties are planted in rows. This is labour intensive, though farmers explained having improvised ways of estimating spacing to limit the additional labour burden. They generally used sticks or strides to estimate the distance from row to row or plant to plant. Other measures used were hands and a hoe's handle. Some farmers used a stick in the beginning and then estimated the distances between the plants and rows using their eyes. Farmers indicated that the high germination rate of improved maize obviates the need for replanting, which saves some labour compared to local maize. Yet, labour use was again higher for improved maize during the rest of the growing season. Due to its sensitivity to the parasitic striga weed (striga hermothica), which is prevalent in Eastern Uganda, improved maize requires more intensive weeding, The spraying of pesticides to mitigate the sensitivity of improved maize to stalk borers and fall armyworm also implies an additional labour requirement. Finally, labour use for improved maize was higher at harvesting due to the higher yields. Harvesting encompasses removing the cobs from stalks, shelling, transporting and drying which all requires a lot of labour (though shelling can also be done using machines).

The use of improved seeds changes relationships with market partners, which may (partly) explain why educated farmers and farmers producing on a larger scale are more likely to adopt. First, it forges new relationships with agrodealers. While local seeds can be purchased at the local market or through exchange with other farmers, farmers travelled long distances to buy improved seeds from trusted agro-dealer shops or seed companies located at sub-county or district towns. The use of pesticides strengthens linkages with input markets even more. Second, it affects relations with output traders. Farmers explained that improved seeds are frequently attacked by weevils during storage. This drawback is also mentioned in other studies (Lunduka et al., 2012; Obaa et al., 2005). Farmers are therefore more eager to sell their produce shortly after harvest when using improved seeds. This may explain why prices are not higher for improved maize although traders prefer it over local maize.

3.6 Discussion and Conclusion

In this paper, we study the adoption of improved maize seeds in Uganda as fluid and iterative. Contrary to most adoption studies, we combine economic and sociological theories. By successively including more data, we show the additional insights that taking a broad perspective of adoption and using mixed methods give.

As a first step, we use cross-sectional data and conventional econometric methods. Based on cross-sectional survey data from 2015/16, we find that 41 percent of farmers used improved seeds though they continue growing local maize as well. Conform the literature, male farmers with more human and natural capital were more likely to adopt. Men seemed to have better access to the technology. Looking beyond the dichotomy of non-adoption/adoption, we find that besides human and natural capital, physical capital increased the extent of adoption. These findings suggest that access to seeds was problematic for poorer farmers and that subsidies or targeted credit programs could help facilitate diffusion. In addition, uneducated farmers appeared to have difficulty in understanding the benefits and use of improved seeds. This suggests that additional extension would be effective as well. However, we must keep in mind that farmers learn more from watching other farmers than from extension officers (Anderson & Feder, 2007). Given the already relatively widespread use of improved seeds, a combination of external stimulus and social learning could be most effective.

As a second step, we introduce data for the two agricultural years before 2015/16 that form a panel with the data used in step one. Whereas the cross-sectional analysis implicitly assumes that adoption is uni-directional (adopters will remain adopters), we can now explicitly show whether this is the case and in addition show whether adoption spreads over time. Interestingly, we observe that adoption is a reversible process for many farmers: 31 percent of farmers who adopted in the first or second year disadopted again afterwards. Though each year we see higher rates of adoption, the adoption rates of the final year (41 percent, allowing for 3 seasons of recycling) largely underestimate the share of farmers using improved seeds at any time during the three years (57 percent). This has important policy implications. Problems with affordability and lack of knowledge seem less widespread than the cross-sectional analysis suggested. The high adoption and disadoption rates suggest that the problem is more complex.

However, the panel data do not give much insight into the nature of these problems. We find that wealthier farmers were more likely to adopt (to a larger extent) and less likely to disadopt. In addition, female farmers were just as likely as male farmers to adopt, but more likely to disadopt. The panel data do not allow us to assess the underlying reasons for the temporal patterns of adoption and disadoption.

As a third step, we therefore add qualitative information. This information shows that farmers liked to grow improved maize for the market, as yields were higher, and traders preferred to buy improved maize. However, farmers did not like improved maize for consumption so that they always cultivated at least a small plot with local varieties. The production of improved maize requires more capital and labour than the production of local maize. Additional labour was required during the peak seasons of planting, weeding and harvesting when labour was not only costly but also difficult to find; and financial capital was needed for the purchase of the relatively expensive seeds and for pesticides. (Continued) adoption was limited by two completely different reasons. First, as we concluded from the quantitative analyses, farmers often lacked the money to purchase the expensive improved seeds. This problem cannot be solved by a one-time subsidy to initiate adoption. Instead, the government and local NGOs could experiment with nudges for setting aside money directly after harvest or attractive credit sources. Second, some farmers had been disappointed by the performance of improved seeds due to the presence of counterfeit seeds in the market. This indicates that seed promotion should include a large component on recognizing improved seeds. The existing electronic certification verification program could be expanded and promoted more widely among farmers. Given the observed strong effect of education on adoption, all activities should be carefully designed to include farmers with only primary education or less.

Our analysis shows that taking a dynamic perspective of adoption and including qualitative as well as quantitative information deepens our insights, changes our conclusions, and results in different policy recommendations. We have shown this by building our analysis from the standard cross-sectional economic analysis, through panel data analysis, to inclusion of data from FGDs and in-depth interviews. This brings up the question whether the qualitative data alone would have led to the same insights and at a much lower cost. We think this is not the case. Indeed, we would have known the perspective of the farmers and experts interviewed, but we would not have known to what extent these perceptions affect the behaviour of the farmers in the region. The combination of quantitative and qualitative data gives the appropriate mix of in-depth information on preferences and broad information on revealed preferences to draw relevant policies conclusions. It is, however, not always necessary to collect expensive panel data. Moser and Barrett (2003) rely on farmer recall on the use of technology in the past five years. As our analysis used the dynamics of (dis)adoption and further relied on relatively stable household characteristics, such a pseudo-panel approach would have worked for this study as well.

Despite the richness of our toolbox and data, we ran into several difficulties during our analysis. First, our three-year panel did not allow detailed study of the determinants of the household-level intertemporal patterns of adoption. As improved maize seeds were not new at the start of the panel and the panel was relatively short, we could not distinguish between early and late adopters. In addition, as the observable determinants of adoption and disadoption are relatively stable, we could not estimate the between-year determinants of changes in adoption using fixed-effect models. Second, we have no information about seed use before the first survey year, which makes it impossible to account for a reasonably period of recycling (three seasons) in the first year. While the latter could have easily be solved by adding an additional question to the survey, the first problem is at least partly inherent in the use of quantitative data. The differences between early and late adopters can be assessed with well-timed panel data, but nuanced intertemporal dynamics are hard to capture using surveys only. We believe that in our study, the use of in-depth interview and FGDs to complement the survey data has at least partly fill this gap.

4

Chapter 4

The Effects of the Adoption of Improved Maize Varieties on Production and Income in Uganda

Chapter 4

The Effects of the Adoption of Improved Maize Varieties on Production and Income in Uganda

Abstract

Certified improved seed is a potentially important input in maize production for rural households in Sub Sahara Africa. This study investigates the effects of certified improved maize varieties in eastern and mid-western Uganda using three waves of survey data from a sample of over 1600 rural households. To overcome the potential biases due to differences between adopters and non-adopters, we use the doubly robust method (fixed effects estimator with inverse probability weighting) to estimate the effects of adoption on maize yields, maize income per hectare, and total crop income. We find evidence of positive significant effects of improved maize varieties on maize yields and crop income. Despite these positive effects, farmers revert to local seeds because of unaffordability and inaccessibility. Therefore, there is need for policies that target not only the adoption but also the continued use of improved maize varieties. In addition, we find that the size of the income effect is larger than could be expected given the maize yield and income effects, which suggests behavioural responses beyond maize production.

Keywords: Improved maize varieties. Production. Income. Fixed effects. Uganda

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4.1 Introduction

In Sub Sahara Africa (SSA), agriculture remains a key sector of the economy and thus important for attaining economic growth. Agricultural growth and development depend on adoption of agricultural technologies like improved crop varieties. Technology adoption could boost agricultural productivity in rural areas where most of the poor live and practice smallholder agriculture. With rapid growth in human population and decreasing farm sizes, production gains should come from yields rather than the expansion of land (Jayne et al., 2014).

Maize is an important crop for smallholder farmers in SSA for both food security and household income. Local governments, development agencies, donors, and international research institutes have therefore heavily supported and invested in the development and dissemination of improved maize varieties. For example, in Uganda alone, 45 maize varieties[4] were released to the market between 2013-2017 (Mabaya et al., 2016; Mabaya et al., 2018 (Revised 2019)). The use of such certified seeds supposedly increases yields and incomes for smallholder households for whom maize is an important crop. However, the presence of low quality seeds in the market limits the potential benefits of purchasing such seeds (Bold et al., 2017). In addition, due to imperfections in capital markets, investments in maize may come at the cost of other crops, limiting their effects on total agricultural income.

Because of the importance of maize, the impact of improved maize seeds on farmers' wellbeing has increasingly received attention (e.g., (Abdoulaye et al., 2018; Bezu et al., 2014; Jaleta et al., 2018; Khonje et al., 2015; Magrini & Vigani, 2016; Manda et al., 2018; Mason & Smale, 2013; Mathenge et al., 2014; Smale & Mason, 2014; Smale et al., 2015; Zeng et al., 2015). Overall, the available evidence suggests that the adoption of improved varieties increases yield, income, and asset values and reduces poverty and food insecurity. However, most studies use cross-sectional data. This limits the options to correct for unobserved differences between adopters and non-adopters, which may severely bias results. Only few studies use panel data, which allow correcting for time-invariant farm or household-specific

[4] Mostly grown maize varieties in the study area are Longe 4, Longe 5/Nalongo, Ssalongo, Longe 7H, Longe 10H.

differences (Mason & Smale, 2013; Mathenge et al., 2014; Smale & Mason, 2014). Yet these studies focus on hybrids, whereas in many settings open pollinated varieties (OPVs) are much more common.

We contribute to the literature by assessing the impact of certified maize seed on smallholder production and income in rural Uganda. Our study is of particular interest for three reasons. First, we use a three-year panel and apply a fixed effects estimator and inverse probability weighting. As explained above, the use of panel data greatly improves the potential for causal inference, but most existing studies have relied on cross-sectional data. Second, OPVs are by far the most popular improved varieties in Uganda (Mabaya et al., 2018 (Revised 2019)). OPVs generally have much lower yield potential than hybrids, which have been object of study using panel data, so their impact may be lower. Third, we analyse the effects of improved seed adoption on outcome indicators along the causal chain: maize yields, maize income, and total crop income. This approach adds an additional validity check compared to the common practice of focusing on the ultimate impact of improved seeds on income, diets or food security, as attribution is easiest for indicators closest to the innovation. Along the causal chain, the validity of estimates is increasingly threatened by additional behavioural responses and contamination factors. These can affect the sign, significance, and size of the effect. By following the impact throughout the chain, we were able to detect potential inconsistencies.

The paper proceeds by presenting the research context and the data, followed by an explanation of the methodology, the results and a concluding section.

4.2 Study area and data

4.2.1 Maize production in Uganda

Maize has been a focus crop for policy as well as technology development in Uganda. Smallholder farmers produce over ninety percent of the country's maize, of which about sixty percent is consumed within the household. Because of its dual purpose as food and cash crop, maize can help improve farmers' income position and food security in Uganda's risky environment with limited market development. Maize grain is also exported to neighbouring countries like Kenya.

Development agencies, donors, and research institutes have for many years supported the development and dissemination of improved varieties to stimulate productivity, resulting in high variety releases for maize compared to other crops such as millet, sorghum and beans (Mabaya et al., 2018 (Revised 2019)). The National Agricultural Research Organisation (NARO) is responsible for research on and initial production of improved varieties. NARO then sells the improved seeds to seed companies who multiply and distribute them to agro-dealers located in major towns or trade centres. Farmers buy mostly from these agro-dealers, though some source directly from the seed companies. This seed system is relatively weak, with agro-dealers complaining about late delivery of seeds by seed companies and low-quality road connections. In addition, seeds of low quality are no exception in the market (Bold et al., 2017). Barriga and Fiala (2020) find no evidence of adulteration but their results are consistent with deterioration of seeds due to poor handling and storage.

Farmers cultivate both improved and local maize varieties. In almost all of Uganda's agro-ecological regions, maize is planted in two growing seasons in a year. For consumption, farmers prefer local varieties, which are relatively sweet and can be stored for longer periods. For sale, they prefer high yields and short maturity periods. Improved maize varieties include hybrids and OPVs, but the latter are far more common: about 90 percent of area under improved maize seed is planted with OPVs (Mastenbroek & Ntare, 2016). Depending on the cultivar, attributes of improved seeds include higher yields, pest and disease resistance, fast maturity, suitability for acidic soils, better nutritional value, and drought resistance (Lee, 2020). The main input is family labour. While improved seeds are promoted as part of a package of seed, fertilizer and good crop husbandry practices, very few farmers use fertilizers (Barungi et al., 2015).

4.2.2 Data collection and sample selection

We use panel data from a project conducted by Tegemeo Institute of Agricultural Policy and Development and Makerere University, Uganda. The panel consists of household survey data from three waves (2013/14, 2014/15 and 2015/16 cropping years) collected from four districts in Uganda: Tororo and Iganga districts in Eastern region and Masindi and Hoima districts in Mid-western region in Uganda. First, the districts were purposively selected from maize growing areas. Second, four sub-counties were randomly selected from each district. Third, fourteen villages were randomly selected from each sub-county, and a list of households drawn for each village. Finally, 10 households were randomly selected from each village. Ultimately, in the first and second waves, data were collected from 2,133 households. In the third wave, 2,035 households were interviewed. Of these households, 1,953 households were interviewed in all three waves. Some households could not be reached due to refusals, unavailability, or dissolution of the household. The households that dropped out were not significantly different from the sample in the panel (see detailed analysis of attrition in (Kamau et al., 2018)). Out of the 1953, there were 1846, 1866 and 1779 who grew maize in year 2013/14, 2014/15 and 2015/16 respectively. 1645 households (84 percent) reported to have planted maize in all the three cropping years.

The survey questionnaire captured information on individual, household, institutional and production characteristics. The individual characteristics include gender, age, and education. The household characteristics include resource endowments, household size, and farm and non-farm assets. Institutional factors include access to extension services, input and output market. Crop production data were collected at plot and seasonal level, with farmers growing two crops per year. For each maize plot and season, data were collected on seed type, seed cost, area planted, fertiliser used, labour used for land preparation, production and amount sold. We used farmer recall in collecting data on the crops and varieties planted, input used, harvest and amount sold, as there was little or no crop production recording. Using farmer recall method may lead to measurement errors in output, input and productivity variables depending on the length of the recall method (Deininger et al., 2012; Wollburg et al., 2020), although not all studies confirm such bias (Beegle et al, 2012). To reduce potential recall bias, the surveys were carried out immediately at the end of each cropping year. The farmers were able to tell whether they used the packaged certified maize seed sold in the agro-shops or seed companies, other (non-certified) purchased seeds, or seeds recycled from the previous harvest.

4.3 Methods

4.3.1 Outcome indicators

We consider three indicators of seed impact, namely maize yields, maize income per hectare, and total crop income. Maize yields were calculated using total quantity of maize harvested divided by the total area planted with maize (hectare). Maize income per hectare was measured as total revenue from maize minus total variable costs excluding family labour divided by the total maize hectare. Crop income is the total revenue from all the crops planted minus the variable costs excluding family labour. Outcome variables were calculated at household level. For robustness, outcome variables were winsorized at five percent on the lower side and five percent on the higher side (5 95) to account for outliers. Winsorizing at one percent at both ends (1 99) gives similar results.

The advantage of this set of indicators is that we can follow impact through the causal chain. The expected direct impact of the use of improved seeds is an increase in yields. If the value of the additional production is higher than the additional costs incurred for the purchase of the relatively expensive seeds and potential complementary inputs, maize income per hectare will increase as well. Logically, as a result of the additional costs in terms of more expensive seeds and potential complementary inputs, the percentage increase in per hectare income is lower than the percentage increase in yields. Similarly, total crop income will increase with maize income, but the effect will be diluted by the presence of other crops and could further decrease if farmers re-allocate high quality resources from other crops to maize production: e.g., if farmer divert their best land from other crops to certified maize production, this will lead to a reduction in the productivity of these other crops.

4.3.2 Estimation strategy

We used a fixed effects estimator to assess the effects of adoption on each outcome variable. Panel data methods help in controlling for time-invariant variables which have not been captured in the data. The fixed effects model is as given below:

$$Y_{it} = \alpha_i + \beta T_{it} + \gamma X_{it} + \lambda_t + \mu_{it}; i = 1, \ldots, n; t = 1, \ldots, T \quad 4.1$$

Where Y_{it} is the outcome indicator for household i at time t. λ_t α_i and λ_t capture fixed effects for household and year respectively (Cameron & Trivedi, 2005). T_{it} is the adoption variable (1 if adopted and 0 otherwise), which may vary by household and year; The adoption status can change, i.e. a household may adopt one-year and not the next. X_{it} are individual controls, such as household and farm characteristics, μ_{it} is the individual specific error term. We clustered standard errors at the village level. The effect of adoption is captured by β.

The two-way fixed-effects model assumes that all households face parallel trends. This may not be a valid assumption when adopters and non-adopters are systematically different. We test the credibility of this assumption by comparing the trend in the outcome indicators between wave one and two of households that first adopted in wave three with those that never adopted:

$$[Y_{i,wave2} - Y_{i,wave1}] = \beta_0 + \beta_1 adopt_{i,wave3} + \beta_2 X_{iwave1} + \varepsilon_i \qquad 4.2$$

where $X_{i,wave1}$ is a vector of household-level controls and time-invariant district controls, and $adopt_{i,wave3}$ is a binary indicator that equals 1 if household i adopted in the final survey wave (2015/16 crop year), and 0 otherwise. Table 4.1 reports the estimates for coefficients β_1. None of the coefficients is significant at the 10 percent level, providing support for our hypothesis that the trends in yield and incomes do not differ significantly between the two groups.

Table 4.1: Tests for parallel trends in outcome variables prior to first adoption in wave 3 (2015/16) (N=846)

Outcome variable (wave2-wave1)[a]	Coefficient	Standard error	p-values
Yield (kg/ha)	-42.26	62.50	0.500
Maize income (Ush/ha)	-27792.88	30089.54	0.357
Crop income (Ush)	140853.2	175094.4	0.422

Source: Own computation using survey data. ***p<0.01. **p<0.05. *p<0.10. (N=846: 220 adopters and 626 non-adopters). [a] The equation used to construct the above table is $[Y_{i,wave2} - Y_{i,wave1}] = \beta_0 + \beta_1 adopt_{i,wave3} + \beta_2 X_{iwave1} + \varepsilon_i$ where $X_{i,wave1}$ is a vector of the controls used in all regressions, plus time-invariant district controls, and $adopt_{i,wave2}$ is a binary indicator that =1 if household i adopted in the 2017 survey wave (2015/16 crop year), and =0 otherwise. Standard errors are clustered at the village level. The coefficients reported in the table are the estimates of β_1.

We combined the two-way fixed effects with the inverse probability (IPW) estimator (Imbens & Wooldridge, 2009). A drawback to using two-way fixed effects is that it is a linear estimator that must be properly specified in order to produce unbiased and consistent estimates. Non-parametric techniques, such as propensity-score matching (PSM), can provide an alternative that has less restrictive assumptions about functional form (Caliendo & Kopeinig, 2008). However, the propensity score is calculated using a logit or probit regression, and this must be properly specified to obtain unbiased estimates. PSM has two key assumptions: unconfoundedness and sufficient overlap. Unconfoundedness implies that controlling for a fixed set of covariates (Xs) removes biases in comparisons between treatment and control units. The covariates values should not change for any farmer when his/her treatment status changes, therefore use of baseline covariates is recommended (Diagne & Demont, 2007; Heckman & Navarro-Lozano, 2004; Wooldridge, 2005). Sufficient overlap implies that households with the same covariates have positive probabilities of adopting and non-adopting the improved maize varieties. Thus, when moving between fixed effects regression and PSM, the researcher exchanges one risk of misspecification for another. Double-robust estimators combine regression and inverse probability weighting to produce unbiased estimates if either model (the propensity score or the regression) is properly specified. Thus, the researcher has two chances of "getting it right" (Bang & Robins, 2005).

The estimation procedure was as follows. First, we estimated the likelihood of adoption using a logit model and generated the propensity scores using the baseline data. Second, we used the (inverse) propensity scores as weights in the fixed effects regression. We used the balanced panel of households who cultivated maize in each of the three survey years. This implies that our results hold for households who consistently grow maize - the incidental maize growers in our sample did not adopt improved maize seeds. We ran the impact regressions only for those that are on the common support to ensure sufficient comparability of adopters and nonadopters.

4.3.3 Control variables

Our set of independent variables for the propensity score estimates consists of characteristics of the head and their household, the resource endowment, and a set of location indicators describing the production environment. Age, gender, and education level of the household head may affect their management capacity and their access to markets and technology. The number of adults and dependency ratio reflects the household's labour endowment and their food requirements. Farm size, the number of livestock units and value of productive assets represent the endowment of physical capital, the scale of production, and the access to other resources. Oxen ownership reflects the timely availability of draft power, a crucial input in production. The production environment is captured in district dummies, household-specific distance to input and output markets and extension. The time-invariant variables among these are also used as controls in the fixed effects estimates (See Table 4.2).

Summary statistics of the sample characteristics are presented in Table 4.2. About ninety percent of household heads are male with mean age of 47-48 years. At least half of the household heads have above primary school level. Half of the household members are dependants with an average of three adults in each household. The total livestock herd kept was 1.25 TLU in 2013/14, 1.37 TLU in 2014/15 and 1.46 TLU in 2015/16. About thirty percent of the maize farmers reported incurring losses due to drought. Households were distributed equally in terms of proportion across districts with about 25 percent of the households located in each district.

Table 4.2: Summary statistics of sample characteristics (N=1953)

Variable	2013/14	2014/15	2015/16
Age of the household head (years)	45.47(14.69)	47.62(14.51)	48.92(14.43)
Gender of the household head (1=Male, 0=Female)	0.89(0.32)	0.88(0.33)	0.87(0.34)
Education (1=above primary education; otherwise=0)	0.48(0.50)	0.47(0.50)	0.47(0.50)
Dependency Ratio ((children+elderly)/total *100)	48.60(20.50)	51.41(19.68)	50.40(20.15)
Number of adults in the household	3.41(1.89)	3.26(1.77)	3.47(1.86)
Land owned (acres)	5.05(12.7)	5.40(11.98)	4.44(8.02)
Oxen ownership (1=Yes, 0=No)	0.10(0.30)	0.11(0.31)	0.12(0.33)
Asset value (UGX; 1,000,000)	1.77(3.32)	2.17(4.10)	2.40(5.92)
Tropical Livestock Unit	1.25(2.69)	1.37(3.12)	1.46(4.14)
Reported loss due to drought (1=Yes, 0=No)	0.21(0.40)	0.27(0.44)	0.35(0.48)
Distance to the nearest extension office (km)	6.33(4.12)	6.33(4.12)	6.33(4.12)
Distance to the nearest agro-dealer (km)	7.77(5.00)	7.77(5.00)	7.77(5.00)
Distance to the nearest produce market (km)	6.86(5.62)	6.86(5.62)	6.86(5.62)
Household is in Hoima district =1, otherwise=0	0.25(0.43)	0.25(0.43)	0.25(0.43)
Household is in Masindi district =1, otherwise=0	0.22(0.41)	0.22(0.41)	0.22(0.41)
Household is in Tororo district =1, otherwise=0	0.27(0.44)	0.27(0.44)	0.27(0.44)
Household is in Iganga district =1, otherwise=0	0.26(0.44)	0.26(0.44)	0.26(0.44)

Source: Own computation using survey data (Standard deviation in parenthesis)

4.3.4 Results of the logit regression

Table 4.3 gives the results of the logit regression for the use of certified seeds in the base year. The results suggest that adopters had more education than non-adopters and owned more land and assets but less livestock, though the sizes of the wealth effects are small. There are also substantial regional differences. However, only seven households were outside the range of the common support, which indicates a large overlap in characteristics between adopters and non-adopters in the sample.

Table 4.3: Adoption of certified maize seed: Logit results using 2013/14 survey round (N=1,645)

Variable	Adoption (1=Yes, 0=No)
Age of the household head (years)	0.005
	(0.028)
Age of the household head squared	-0.0003
	(0.0003)
Gender of the household head (1=Male, 0=Female)	0.310
	(0.228)
Education (1=above primary education; otherwise=0)	0.480***
	(0.125)
Dependency Ratio	0.001
	(0.004)
Number of adults in the household	0.059
	(0.041)
Land owned (acres)	0.053***
	(0.018)
Land owned squared	-0.0004
	(0.0002)
Whether the household owned an Oxen (1=Yes, 0=No)	0.160
	(0.212)
Asset value (UGX; 1:1,000,000)	0.092**
	(0.037)
Tropical Livestock Unit	-0.103**
	(0.044)
Whether a household reported experiencing loss due to drought	-1.161
(1=Yes, 0=No)	(0.151)
Distance to the nearest extension office (km)	-0.017
	(0.017)
Distance to the nearest agro-dealer (km)	-0.012
	(0.014)
Distance to the nearest produce market (km)	0.003
	(0.014)
Household is in Masindi district =1, otherwise=0	2.084***
	(0.199)
Household is in Tororo district =1, otherwise=0	0.655***
	(0.218)
Household is in Iganga district =1, otherwise=0	0.649***
	(0.239)
Constant	-2.348***
	(0.701)
N	1,645

Source: Own computation using survey data (Clustered standard errors in parenthesis)

4.4 Results and discussion

4.4.1 Descriptive statistics

In each of the survey years, more than ninety percent of households reported that they had grown maize (Table 4.4). The use of certified seeds increased from 25 percent of households in 2013/14 to 40 percent in 2015/16. This was not simply an expansion of the number of farmers growing improved varieties: farmers both adopted and disadopted. More concretely, 31 percent of farmers who adopted in the first or second year, disadopted again afterwards. We explored the reasons for this behaviour during qualitative interviews. The key reasons given by farmers were lack of money to purchase the expensive improved seeds and disappointment with the performance of improved seeds due to the presence of counterfeit seeds in the market. (See Chapter 3 for an in depth analysis of adoption and disadoption.)

Table 4.4: Proportion of households that adopted in the three years (N=1953)

Variable	2013/14	2014/15	2015/16
Households that planted maize	94.6%	95.5%	91.1%
Households that planted certified maize	25.4%	34.2%	37.9%

Source: Own computation using survey data

The mean land size under maize cultivation was about 0.8 hectares (Table 4.5). This area may contain other crops intercropped with maize since the survey did not specify whether maize was under mono cropping or intercropping. Area under certified maize accounted for about 20 percent, 31 percent and 34 percent of a farmer's land under maize in 2013/14, 2014/15 and 2015/16 respectively. Considering only those farmers purchasing certified maize seeds, this was on average 75 percent.

Table 4.5: Area under maize

Variable	2013/14	2014/15	2015/16
Total area under maize (hectares)	0.77(0.90)	0.87(1.03)	0.81(0.92)
Total area under certified maize (hectares)	0.23(0.70)	0.31(0.72)	0.34(0.79)
N	1953	1953	1953
Certified maize area/total maize area (households who planted maize)	0.20(0.37)	0.27(0.40)	0.31(0.41)
N	1848	1866	1779
Certified maize area/total maize area (households with certified maize)	0.76(0.28)	0.75(0.28)	0.76(0.28)
N	464	622	701

Source: Own computation using survey data

The mean values of the outcome variables for adopters and non-adopters of certified maize are shown in Table 4.6Table *4.6*. Uganda experienced El-Nino in 2015 and 2016 causing water logging and on and off drought (Anyadike, 2017; UNMA, 2015, 2016) and thus decreasing yields (FAO, 2017b). Interestingly, in our sample only yields for improved maize decreased substantially over the years. This is consistent with Lee (2020) observation that only 18 out of 71 available varieties were drought resistant. Yet adopters had statistically significant higher yields in all three years. For adopters, maize incomes per hectare decreased in 2014/15 but increased in 2015/16: the decrease in productivity resulted in an increase in maize prices (FEWSNET, 2017a; WFP, 2017). For non-adopters, incomes increased throughout the survey period. Adopters had statistically significant higher maize income per hectare in the first two years and statistically significant higher total crop income in all three years.

Table 4.6: Outcome indicators for adopters and non-adopters of certified seed (households growing maize in all three survey rounds)

Year	2013/14			2014/15			2015/16		
Variable	Adopters	Non-adopters	T-test	Adopters	Non-adopters	T-test	Adopters	Non-adopters	T-test
Improved seed									
Yield (kg/Ha)	1803 (970)	1061 (745)	***	1434 (842)	1141 (731)	***	1295 (786)	1157 (868)	***
Maize income/Ha	672,853 (427,077)	405,280 (317,105)	***	554,652 (449,167)	502,001 (391,462)	**	638,642 (490,006)	604,544 (504,902)	
Crop income	2,583,840 (2,486,528)	1,749,061 (1,805,046)	***	2,615,840 (2,512,034)	2,203,146 (2,088,804)	***	3,553,505 (3,889,572)	2,633,095 (2,768,125)	***
N	464	1,181		622	1,023		701	944	

Source: Own computation using survey data (Standard deviation in parenthesis) ***p<0.01. **p<0.05. *p<0.10.

4.4.2 Impact estimates

Table 4.7 presents the average treatments effects of adopting improved maize varieties on yield and income. Adoption of improved maize varieties was associated with increases in maize yields, maize income per hectare and crop income. However, the increase in maize income per hectare was small and not statistically significant. The average difference in maize yield for similar adopters and non-adopters was about 133 kg/hectare, which reflects a yield increase of 13 percent. This is due to the seeds themselves and possibly associated increases in the use of additional inputs like labour and fertilizers (though the latter are rarely used by the farmers in our sample). The presence of counterfeit or otherwise low quality improved seeds pushes our impact estimates down; The effect we observe is the weighted average impact of counterfeit/low quality and true/well-preserved certified seeds. Bold et al. (2017) estimate that the average bag of hybrid seeds used by farmers in Uganda contains only about 50 percent of healthy hybrid seeds. Generalizing this number to all certified seeds used in our sample, this would imply that we observe only about half of the potential yield impact of proper improved seeds. In addition, what we observe is the average impact over three years with different weather conditions.

Table 4.7: Effect of adoption of improved maize varieties on yield and income

Outcome variable	Yield (kg/Ha)	Maize income (UgSh/Ha)	Crop income (UgSh)
Impact of adoption using FE-IPW	132.72***	3,828	490,191**
	(40.44)	(22,682)	(201,519)
Mean outcome for non-adopters	1,114.81	496,531	2,157,141
	(13.95)	(7,379)	(39,971)
Impact /non-adoption outcome	0.13	0.02	0.21
Sample mean outcome	1,244.15	540,163	2,448,600
	(11.92)	(6,210)	(37,571)
N	4,914	4,914	4,914

Source: Authors' computation using survey data (Robust standard errors in parenthesis) ***p<0.01. **p<0.05. *p<0.10.

Maize income per hectare increased by 3,828 Ugandan shillings per hectare compared to farmers who did not plant certified maize. This means that the value of the higher yield outweighed the higher costs associated with the purchase of costly certified seeds, but only slightly. Yet the percentage increase per hectare income (2 percent) is lower than the percentage increase in yields. The reason is that certified seeds are costly. Farmers using certified seeds do not necessarily receive higher prices for their produce. Traders generally do not differentiate their prices between different types of maize (Mastenbroek & Ntare, 2016).

Total crop income was significantly higher for adopters. We had expected the increase in total crop income to be lower than the increase in total maize income. Certified seeds are expensive and working capital is scarce in the study area. In addition, farmers may have allocated additional labour their highest quality land to complement the high-quality seeds. All this would have gone at the expense of other crops, thus limiting or even cancelling the income effects of the certified maize seeds. Yet, farmers cultivate about 0.8 hectares of maize on average, and the estimated increase in crop income is much higher than the increase in maize income per hectare. This suggest that adopters generate higher incomes not only for maize but also for other crops.

The most obvious explanation for this finding would have been that we are not (only) measuring the effect of the certified seeds but (also) the effect of better farmers with higher quality resources. However, this explanation does not hold given our use of fixed-effect regression: What our estimates measure is the average difference in crop income when using or not using certified seeds for the same farmer.

Possible explanations lie in the behaviour and choices of the farmers (Bulte et al., 2020). A potential explanation could be that farmers adopt and disadopt depending on their specific situation at the time: as explained before, almost one third of farmers who adopted during the first and/or the second round no longer used certified seeds at a later survey round. An important reason for this behaviour was that in some years farmers simply did not have the cash to purchase seeds. Fluctuations in health and other circumstances may have had similar effects. Alternatively, if farmers purchased varieties that are tolerant to poor soils, they could have allocated their better plots to other crops. In general, our findings suggest that when farmers can and do invest in certified maize seeds, they invest more in agriculture in general. This would imply that, even when controlling for differences in farming skills and farm quality through fixed effects, we cannot attribute all differences in maize yields and income between adopters and nonadopters to maize seed adoption.

Summarizing, after controlling for differences in farming skills and farm quality, we find substantial positive effects of certified seeds on maize yields and crop incomes. Our estimates may deviate from the "pure" effect of quality seeds for two reasons with opposite effects. First, ours are estimates are likely to be lower due to the high presence of low-quality seeds. Second, our estimates may be biased upwards because farmers seem to purchase certified seeds especially when the circumstances for production are good.

4.5 Conclusion and policy recommendations

We analyse the effects of adoption of improved maize varieties on yield and income using data obtained from households in rural Uganda for the year 2013/14, 2014/15 and 2015/16. We use panel data and a doubly robust estimator (fixed effects estimator with IPW) to overcome the potential biases due to differences between adopters and non-adopters. The findings show that, despite the presence of low quality seeds in the market (Barriga & Fiala, 2020; Bold et al., 2017), the use of improved maize varieties increased productivity and crop income but not the maize income per hectare.

Yet although more than ninety percent of farmers reported growing maize, less than forty percent cultivated improved varieties. Farmers frequently reverted to local maize varieties, even though they obtained higher yields with the improved varieties. Sometimes they simply did not have the cash to purchase the improved seed. In addition, agro-dealers mentioned that seed companies regularly delayed delivery of the seeds. Therefore, there is need for policies aimed at not only enhancing initial adoption of improved varieties but also ensure continued use. Improved seeds should be made more accessible and affordable through increasing the efficiency of input supply and the availability of credit and savings mechanisms. Development of local markets and road infrastructure is paramount in not only the accessibility of improved varieties but also the output markets.

Not all differences in crop income between adopters and nonadopters could be attributed to higher maize yields, even after correcting for differences between farm quality and farming capabilities. There may be incidental differences between farmers. During qualitative interviews, farmers mentioned that in some years they just did not have enough cash at hand to purchase seeds. This lack of cash may affect their entire production system. Alternatively, farmers may purchase maize seeds that can be grown on poor soils, so that they can allocate the better soils to other crops. With observational data, it is virtually impossible to correct for such time-variant unobserved differences between adopters and disadopters, even in the (rare) presence of panel data.

We think that our study has important implications for the interpretation of the results from other adoption studies. While our choice of outcome indicators allowed us to assess the consistency between the various results thus teasing out effects that cannot be explained by the use of certified seeds, this is not often done in other studies. Several of the studies we reviewed do not report yields and incomes for the crop involved, but directly focus on household income, consumption, expenditures or food security. We hypothesize that the observed effects are biased upwards for the reasons explained above. The upward bias may be even higher as most of these studies use cross-sectional data, which limits their ability to control for self-selection compared to our panel data study.

Appendix

Table A4.1: Tests for parallel trends in yield prior to first adoption in wave 3 (2015/16)

	Coef.	Std. Err.	t
Impact of adoption at year 3 (2015/16)	-42.26	62.50	0.68
Dependency Ratio	-0.71	1.86	-0.38
Number of adults in the household	26.15	22.33	1.17
Whether the household owned an Oxen (1=Yes, 0=No)	-3.93	102.20	-0.04
Asset value (UGX; 1:1,000,000)	20.44	19.59	1.04
Tropical Livestock Unit	-14.60	47.49	-0.65
Whether a household reported experiencing loss due to drought (1=Yes, 0=No)	-140.80**	66.20	-2.13
Constant	58.18	162.95	0.36
N	846		
Prob > F	0.1332		
R-squared	0.0110		

***p<0.01. **p<0.05. *p<0.10.

Table A4.2: Tests for parallel trends in maize income per hectare prior to first adoption in wave 3 (2015/16)

	Coef.	Std. Err.	t
Impact of adoption at year 3 (2015/16)	-27792.88	30089	-0.92
Dependency Ratio	-871.72	859.15	-1.01
Number of adults in the household	6145.20	10814.44	0.57
Whether the household owned an Oxen (1=Yes, 0=No)	-30573.61	51592.22	-0.59
Asset value (UGX; 1:1,000,000)	20943.72**	10220.27	2.05
Tropical Livestock Unit	-20922.01*	11652.75	1.80
Whether a household reported experiencing loss due to drought (1=Yes, 0=No)	78462.91**	32408.61	-2.42
Constant	146328.4**	73838.14	1.98
N	846		
Prob > F	0.0.450		
R-squared	0.0165		

***p<0.01. **p<0.05. *p<0.10.

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Table A4.3: Tests for parallel trends in crop income prior to first adoption in wave 3 (2015/16)

	Coef.	Std. Err.	t
Impact of adoption at year 3 (2015/16)	140853.2	175094.4	0.80
Dependency Ratio	886.62	4456.14	0.20
Number of adults in the household	88331.94	57552.03	1.53
Whether the household owned an Oxen (1=Yes, 0=No)	184458.3	314663	0.59
Asset value (UGX; 1:1,000,000)	94650.06	61825.63	1.53
Tropical Livestock Unit	-100436.4	84705.64	-1.19
Whether a household reported experiencing loss due to drought (1=Yes, 0=No)	-336603.1	177739.2	-1.89
Constant	86391.33	365027	0.24
N	846		
Prob > F	0. 0688		
R-squared	0. 0164		

***p<0.01. **p<0.05. *p<0.10.

Table A4.4: Adoption of certified maize seed: Logit results using 2013/14 survey round

Variable	Coef.	Std. Err.	z
Age of the household head (years)	0.005	0.028	0.18
Age of the household head squared	-0.0003	0.0002	-1.05
Gender of the household head (1=Male, 0=Female)	0.310	0.228	1.36
Education (1=above primary education; otherwise=0)	0.480***	0.125	3.84
Dependency Ratio	0.001	0.004	0.38
Number of adults in the household	0.059	0.041	1.44
Land owned (acres)	0.053***	0.018	2.95
Land owned squared	-0.0004	0.0002	-1.58
Whether the household owned an Oxen (1=Yes, 0=No)	0.160	0.212	0.76
Asset value (UGX; 1:1,000,000)	0.092**	0.037	2.52
Tropical Livestock Unit	-0.103**	0.044	-2.33
Whether a household reported experiencing loss due to drought (1=Yes, 0=No)	-0.161	0.151	-1.07
Distance to the nearest extension office (km)	-0.017	0.017	-1.03
Distance to the nearest agro-dealer (km)	-0.012	0.014	-0.85
Distance to the nearest produce market (km)	0.003	0.014	0.22
Household is in Masindi district =1, otherwise=0	2.084***	0.199	10.47
Household is in Tororo district =1, otherwise=0	0.655***	0.217	3.01
Household is in Iganga district =1, otherwise=0	0.649***	0.239	2.71
Constant	-2.348***	0.701	-3.35
N	1,645		
Prob > chi2	0.0000		
Pseudo R2	0.1308		

***p<0.01. **p<0.05. *p<0.10.

Table A4.5: Effect of adoption of improved maize varieties on yield

	Coef.	Std. Err.	t
Impact of adoption	132.72***	40.44	3.28
Survey			
Year 1 (2014/15)	-133.52***	32.05	-4.17
Year 2 (2015/16)	-257.25***	38.90	-6.61
Dependency Ratio	-1.47	1.94	-0.76
Number of adults in the household	-10.54	21.94	-0.48
Whether the household owned an Oxen (1=Yes, 0=No)	-81.10	57.84	-1.40
Asset value (UGX; 1:1,000,000)	23.64*	13.72	1.72
Tropical Livestock Unit	-12.54	17.86	-0.70
Whether a household reported experiencing loss due to drought (1=Yes, 0=No)	-16.87	32.88	-0.51
Constant	1590.07***	163.08	9.75
sigma_u	595.80		
sigma_e	680.96		
Rho	0. 4336		
N	4,914		
R-sq:	within = 0. 0476 between = 0. 1240 overall = 0. 0397		
Prob > F	0.0000		

***p<0.01. **p<0.05. *p<0.10.

Table A4.6: Effect of adoption of improved maize varieties on maize income per hectare

	Coef.	Std. Err.	t
Impact of adoption	3,828	22,682	0.17
Survey			
Year 1 (2014/15)	-5,384.61	19,356.72	-0.28
Year 2 (2015/16)	64,903.65***	22,263.21	2.92
Dependency Ratio	-596.03	1,123.24	-0.53
Number of adults in the household	-13,163.31	12,599.43	-1.04
Whether the household owned an Oxen (1=Yes, 0=No)	-46,982.44	32,930.09	-1.43
Asset value (UGX; 1:1,000,000)	15,513.32**	6,71790.80	2.31
Tropical Livestock Unit	-9.144.18	9,149.90	-1.00
Whether a household reported experiencing loss due to drought (1=Yes, 0=No)	4,576.78	18,188.2	0.25
Constant	659,025***	89,827.25	7.34
sigma_u	301,562.14		
sigma_e	377,498.92		
Rho	0. 3896		
N	4,914		
R-sq:	within = 0. 0245 between = 0. 0252 overall = 0. 0283		
Prob > F	0.0021		

***p<0.01. **p<0.05. *p<0.10.

Table A4.7: Effect of adoption of improved maize varieties on crop income

	Coef.	Std. Err.	t
Impact of adoption	49,190.5**	201,519.2	2.43
Survey			
Year 1 (2014/15)	370,222***	109,061.9	3.39
Year 2 (2015/16)	1,082,451***	142,779.5	7.58
Dependency Ratio	18,657.88**	8,336.67	2.24
Number of adults in the household	312,962.2 ***	94,788.68	3.30
Whether the household owned an Oxen (1=Yes, 0=No)	265,708.9	364,733.4	0.73
Asset value (UGX; 1:1,000,000)	85,693.62*	45,248.51	1.89
Tropical Livestock Unit	-47,643.06	69,639.34	-0.68
Whether a household reported experiencing loss due to drought (1=Yes, 0=No)	241,584.9	180,18.1	1.34
Constant	-87,256.58	779648.2	-0.11
sigma_u	1798826.8		
sigma_e	2596098.4		
Rho	0. 3244		
N	4,914		
R-sq:	within = 0. 0800 between = 0. 1345 overall = 0. 1014		
Prob > F	0.0000		

***p<0.01. **p<0.05. *p<0.10.

Chapter 4

5

Chapter 5

Livelihood strategies and dynamics among smallholder farmers: Evidence from Eastern and Mid-western Uganda

Chapter 5

Livelihood strategies and dynamics among smallholder farmers: Evidence from Eastern and Mid-western Uganda

Abstract

In most sub-Saharan African (SSA) countries, rural households largely depend on agriculture for both subsistence and income. However, many households are increasingly engaging in off-farm activities to supplement their income. This study investigates the livelihood dynamics in Uganda using two waves of panel data of 2035 households. We use a two-step method to cluster the livelihoods; Wards linkage and k-means cluster. Multinomial logit model (MLM) was used to identify the determinants of a household's livelihood strategy choices and transition matrices were used to assess the livelihood strategies dynamics. We find evidence that there are five livelihood strategies; all strategies included annual farming and only one strategy was not diversified. There was little change in distribution of household over the strategies. Age, education, household size, dependency ratio, and location were important factors in determining the likelihood of participating in a strategy. Non-farm livelihood strategies had the highest average per capita income compared to farm strategies. Surprisingly, the farm strategies were the most stable. Use of improved seeds for maize and beans were similar between livelihood strategies. Limited profitability of annual farming could be the reason for resistance to use improved seeds. This calls for policies to not only improve the involvement in non-farm activities but also farm activities especially use of improved technologies.

Keywords: Livelihood strategies. Dynamics. Per Capita Income. Uganda

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5.1 Introduction

In most sub-Saharan African (SSA) countries, rural households largely depend on agriculture for both subsistence and income (Christiaensen, 2017). As a consequence, growth in agricultural productivity is deemed necessary for higher incomes and economic development in rural areas (Block, 1994). Development agencies have been working towards transforming smallholder agriculture to increase agricultural productivity through better access to technologies such as high-quality seed and fertilisers. Yet in many cases productivity remains low, and farm size is decreasing due to a growing population (Headey & Jayne, 2014; Muyanga & Jayne, 2014).

Many households therefore increasingly engage in off-farm activities to supplement their income. Depending on their constraints and opportunities, they diversify their income sources across farm and non-farm activities to survive and overcome distress or to accumulate wealth/assets and improve households' living standards (Nagler & Naudé, 2017). Farm and non-farm activities are highly interlinked through production, consumption and investment, both at regional and at household level (Davis et al., 2017). For example, as part of a diverse livelihood strategy, non-farm income can positively influence investment in improved agricultural technologies (Savadogo et al., 1994). Conversely, agricultural resources and income can be invested in non-farm businesses. Understanding the complexity of livelihood strategies, particularly the combination of farm and non-farm activities/employment, will help in formulating appropriate policy for improving the livelihoods of the rural poor.

Rural livelihoods are non-static, with the current combination of economic activities providing a snapshot of a livelihood pathway or dynamic trajectory (de Haan & Zoomers, 2005; Scoones, 2009). Households respond to opportunities and pressures (Barrett et al., 2005; Dorward et al., 2001); and livelihood strategies change over time depending on the resources available, contextual factors and pressures (Ellis, 2000; Scoones, 2009). Exploring livelihood transitions will help us understand the dynamics of rural livelihoods and the constraints and opportunities that rural households encounter. Yet quantitative studies tend to rely on cross-sectional studies and fail to capture these dynamics, which limits their relevance for understanding the intricacies of household decisions and constraints. A recent example is the study by Wichern et al. (2017) of livelihood strategies in Uganda based on the 2011/12 World Bank LSMS data. Exceptions are studies by Jiao et al. (2017), Sun et al. (2021), , Walelign et al. (2017) and Zhang et al. (2019) for selected Asian countries, and (Van den Berg, 2010) for Nicaragua.

This study contributes to the livelihood strategies literature by assessing the livelihood strategy dynamics in Uganda. We focus on the dynamics using two waves of panel data from 2035 households in Eastern and Western regions in Uganda during the period 2013-2016. To the best of our knowledge, this is the first paper to apply this approach to SSA. In contrast to other regions of the world, specialisation in agriculture is still the norm in rural Africa. In Uganda, over 40 percent of rural households earn more than 75 percent of their income from farming (Nagler & Naudé, 2017). In addition, Africa follows a deviating pattern of off-farm diversification, with a small role for labour markets and a focus on small informal businesses. Comparable to the average across six countries in Africa, 42 percent of rural households in Uganda engaged in non-farm enterprises in 2010/2011, which contributed on average 21 percent of total income, compared to five percent for agricultural wages and 13 percent for non-agricultural wages (Nagler & Naudé, 2017). Acknowledging the central role of agriculture in the country and contrary to related studies focussing on Asian countries, we do not consider farm production as a uniform category but distinguish annual and perennial crop production. In addition, we analyse differences in on-farm diversification, market orientation of crop production, and use of modern crop varieties between livelihood strategies to increase insight into farm - non-farm linkages.

Specifically, the study answers the following questions: 1) What are the livelihood strategies in rural Uganda?; 2) What are the determinants of livelihood strategy choices?; 3) What are the livelihood strategy dynamics among the rural households?; 4) What are the income outcomes among the livelihood strategies?; 5) Are there differences in crop production, sales and use of improved varieties between the livelihood strategies? We used cluster analysis to determine households' different livelihood strategies in each wave and changes in livelihood strategies between waves. A multinomial logit model was used to analyse the determinants of the chosen livelihood strategy. We complemented our analysis with qualitative data, asking farmers about their activities in recent years.

The structure of the paper is as follows. Section 2 presents the conceptual and theoretical framework. Section 3 presents the study area, data collection and data analysis. Section 4 presents the livelihood strategies, their determinants, the dynamics of livelihood strategies, and farm activities in each livelihood strategy.

5.2 Livelihood strategies

A livelihood strategy (LS) is the range and combination of activities that a household chooses to undertake to achieve their desired livelihood outcomes or to secure optimum quality of life (Ellis, 2000; Walker et al., 2001). This process involves assets, activities, and outcomes of each strategy. Rural livelihood strategies are influenced by endowments of productive assets, particularly land and labour (Jansen et al., 2006). Characteristics of households, e.g. education, seasonality and demand of goods/services, also affect the selection of livelihood choices and outcomes. Poor endowed households diversify their livelihood for survival, whereas rich endowed households diversify to accumulate wealth and income. Rural households adjust their livelihood strategies over time to sustain their livelihoods (Ellis, 2000; Haggblade et al., 2010; Scoones, 2009). A household's decision to shift from one strategy to another is affected by their available assets and their living conditions. New opportunities for households to engage in other strategies are created as time passes – by either accumulating assets or removing constraints imposed by certain conditions, e.g. infrastructure. Households can therefore choose activities to increase incomes either permanently or temporarily. Negative shocks can occur between periods, thereby affecting the strategy choices, income and overall wellbeing of a household (Barrett, Reardon, et al., 2001; Ellis, 1998, 2000).

Rural household members allocate their labour to farm and non-farm activities depending on members' availability and capability. Land is allocated to farming activities, which can be for subsistence, income generation, or both. When a household adopts a more remunerative strategy, household income increases, whereas a less remunerative strategy will decrease household income. Households may earn the same income by staying in the same strategy or by switching to a strategy that is equally remunerative. Households adapt their livelihood strategies either to smoothen out their consumption or to protect against income shocks before they happen (ex-post strategies or ex-ante strategies). Ex-post strategies include selling livestock and assets (Dercon, 2002; Kazianga & Udry, 2006), off-farm employment (Haggblade et al., 2007), and borrowing from micro-finance institutions, friends and relatives (Pan, 2009). Ex-ante strategies include saving for future use (Paxson, 1992), crop diversification (Makate et al., 2016; Mango et al., 2018), adoption of agricultural innovations such as drought-tolerant varieties (Phiri & Saka, 2008) and off-farm activities (Reardon et al., 2007). Household members can engage in more than one activity at the same time (concurrent diversification), shift to different activities over time (temporal diversification), or engage in more than one activity at different locations (spatial diversification) (Goulden et al., 2013).

5.3 Data and methods

5.3.1 Study area

The research was carried out in four districts in Uganda – Iganga and Tororo districts in Eastern region, and Hoima and Masindi districts in Mid-western region. Uganda has a favourable climate and relatively good soils for agricultural production (FAO, 2015). Rural households rely on rain-fed agriculture, which makes them vulnerable to weather fluctuations (GoU, 2015; Nyasimi et al., 2016). Crop productivity has been affected by frequent seasonal dry spells and extended lean periods (FAO, 2015). This may have affected the livelihood strategies over time.

The main economic activity in our study area is farming. The most grown crops are maize, beans, cassava, groundnuts, sweet potatoes and bananas. Cowpeas, sorghum and millet are also grown in Tororo district in Eastern region. Rice is grown in Hoima, Tororo and Iganga districts. The main perennial crops were coffee, bananas and fruit trees like jackfruit and avocado. Besides crop production, farmers typically have a small number of cattle, goats, pigs and poultry. Household members engage in small-scale non-farm enterprises such as brickmaking, trading food and non-food commodities, kiosk ownership, tailoring, making and selling alcohol (fermented grain), transport (boda-boda), repairing bicycles, carpentry, and burning and selling charcoal. There is limited additional wage labour. Salaried jobs comprise professions for local businesses, for example hairdressers, tailors, domestic workers, and shops, and some qualified professions such as teacher and civil servant. Casual employment consists of seasonal farm labour and construction work.

5.3.2 Data collection

We use a panel data set collected between 2013 and 2016. The data were collected in four randomly selected sub-counties from each of the four districts. Fourteen villages were randomly selected from each of the sub-counties, and 10 households were randomly selected from each village. Data were collected in three waves, each wave covering a cropping year: 2013/2014, 2014/2015, and 2015/2016. For this paper, we only use the first and the last waves, as data for occupation of household members were unreliable during the second wave. In the first wave, 2133 households were interviewed. 2035 of these were re-interviewed in the second wave, resulting in an attrition rate of 4.6 percent. Reasons for not reaching households were refusals, unavailability, or dissolution of the household. The households that dropped out were not significantly different from the sample in the panel (Kamau et al., 2018). Data were collected using a structured quantitative questionnaire, farmers' in-depth interviews, focus group discussions (FGDs) and key informant interviews. Focus group discussions with farmers and in-depth interviews with farmers were held after the final survey (September/October 2017).

Survey data include crop types, types of livestock kept, demographic characteristics, assets, and sources of income for each household (from crop production, livestock production, off-farm activities). Data on crop production were collected for a full cropping year in each survey. Data on income were collected for the same 12-month period prior to the interview. Data on household characteristics such as age, education, household size, occupation of each household member and farm characteristics such as land owned/cultivated were also collected.

The qualitative data (FGDs and farmer in-depth interviews) were conducted by the first author with the aid of a research assistant in each district who assisted in interpretation from English to the local language using semi-structured questionnaires. Men and women were invited to the same FGDs through the village elder and interviewed together. FGDs provided in-depth understanding of the different sources of income in the community, crops grown in the area, seasonality, and their coping strategies during the low seasons. For farmer in-depth interviews, we interviewed either the household head or the spouse.

5.3.3 Quantitative data analysis

5.3.3.1 Household income

Total household income is the income for the 12 months before the interviews were conducted. It consists of different sources of income: crop production, salaried employment, wages, and non-farm self-employment. We did not include the livestock income in our analysis as the associated data were highly unreliable. The household size was adjusted based on the length of time a member was part of the household for the whole year (FTE). For each household member we calculated the full-time equivalent (FTE) where we divided the number of months stayed in the household by 12 months. A household member is any individual who in the last 12 months has lived within the household for at least one month during the previous year. Per capita income was calculated by dividing the household income by the number of household members in a household. Per capita income reflects the average income per household member.

5.3.3.2 Analysis of livelihood strategies

In this study, we follow the underlying principle that asset allocation reflects the households' livelihood strategy and income is an outcome of the choice of livelihood strategy (Van den Berg, 2010). The livelihood strategies were therefore quantified based on the use of the main household assets, which are labour and land (Jansen et al., 2006). Land and labour proportions were used instead of absolute values to reflect the chosen productive activities. Land allocation was separated into annual and perennial crops. Labour allocation was separated into four activities: farm production, self-employment, casual employment, and salaried employment for each adult household member. Labour allocation to the four activities is defined as the share of available family labour spent on each of the four main activities. Due to data limitations we were not able to separate the farm labour into crop production and livestock production.

We use a two-step procedure for livelihood strategy clustering for each year, using the balanced panel of 2035 households. First, we use Ward's linkage to cluster households and Euclidean distance squared as similarity measure to determine the number of clusters. We generated a hierarchical tree/dendrogram to show the linkage points and calculated statistics for each cluster. Based on these, we determined the number of clusters. Second, we used k-means cluster analysis to correct observations at the boundaries between clusters for possible misclassification, using the number of clusters and the means of each variable of the Ward's linkage clustering as starting values.

We used a multinomial logit model (MLM) to identify the determinants of a household's livelihood strategy choices. MLM is mostly used to analyse dependent variables with more than two unordered outcomes (Wooldridge, 2010). This model predicts the likelihood of a household with given characteristics choosing a livelihood strategy. We are interested in the determinants of a household's livelihood choices at the end of the project (2015/16). The model is:

$$\Pr(y_{it} = j | y_{it-1}, x_{it-}\ ) = \frac{\exp(x_{it-1}\beta_j + y_{it-1} \propto_j)}{\sum_{k=0}^{m} \exp\,(x_{it-1}\beta_j + y_{it-1} \propto_j)}$$

$$i = 1,2,3,\ldots,N \tag{5.1}$$

Where y_{it} is household's livelihood strategy in 2015/16, x_{it-1} are the explanatory variables in 2013/14, β_j is the associated coefficient vector and $\propto_j$ is the coefficient vector. We include the human, natural, and financial capital variables that may influence households' livelihood strategy choices. We calculate relative risk ratios to determine the probability of choosing a specific livelihood strategy over the baseline strategy.

To assess the livelihood strategies dynamics, we used transition matrices. We determine the percentage of households that maintain/shift their livelihood strategy between the two cropping years given the initial strategy. In addition, we present income statistics, crops grown, and livestock kept for different livelihood strategies. The income variables were winsorized at one percent on the lower side and higher side (1 99) to account for outliers. To rank the livelihood strategies, we used stochastic dominance analysis. We compare the income distribution between two livelihood strategies considering the cumulative density for every possible income level.

5.4 Results and discussion

5.4.1 Cluster analysis results for livelihood strategies

The cluster analysis results show that there are five clusters (see Table A5.1 for details). Each household was assigned to a livelihood strategy for 2003/14 and 2015/16 based on their resource allocation to different activities. The names of the livelihood strategies are associated with the most prominent activity or activities. The results show that all strategies included annual farming and only one strategy was not diversified. In 2013/14, the main livelihood strategy was specialisation in annual farming, with 53 percent of households grouped in this cluster (Table 5.1). For other livelihood strategies, households engaged substantially in other productive activities in addition to annual farming: perennial farming, casual employment, salaried employment, and self-employment. The second important livelihood strategy is perennial/annual farming with 22 percent of households, and the third livelihood strategy was self-employment/annuals with 15 percent of households. The remaining two livelihood strategies were adopted by less than 10 percent of households.

The livelihood strategies in 2015/16 were comparable to those in 2013/14, and there was little change in distribution of household over the strategies. The proportion of households engaging in activities other than annual farming increased by 5 percent points. Most notably, there was an increase in households in the perennial/annual farming cluster. This can be explained by the introduction of a government programme promoting the cultivation of coffee and fruit trees (NAADS, 2018). The share of households in the self-employment cluster decreased slightly, whereas the other shares were identical to those in 2013/14.

Data from qualitative data support the above strategies: although most of the FGD participants were primarily growing crops, some households combined non-farm activities with farming. Households invested in businesses such as trading crop and livestock, brick-making and charcoal burning. As one farmer explained, “My husband used to purchase food using income generated from produce trade”. Another farmer added, “We use the income from my husband’s business for school fees, basic needs and medication” (farmer interview notes, 2017). Households provided casual labour to other farmers, primarily for sugarcane production (FGD, 2017).

The results show that annual farming is important for all rural households in Eastern and Mid-western Uganda. Besides annual farming strategy, the other four livelihood strategies revolve around more than two activities. This confirms the evidence from past studies which indicate that rural households diversify their livelihoods to reduce risks that prevail in a rural farm setting (e.g. weather changes) (Liu & Lan, 2015; Nielsen et al., 2013), to respond to opportunities, or for survival (Barrett et al., 2005; Dorward et al., 2001).

Table 5.1: Distribution of livelihood strategies in the sampled households (N=2035)

Year	Self-employment/ annuals	Annuals	Casual employment/ Annuals	Salaried employment/ annuals	Perennials/ annuals
2013/14	0.15	0.53	0.04	0.06	0.22
	(0.36)	(0.50)	(0.19)	(0.23)	(0.41)
2015/16	0.14	0.48	0.04	0.06	0.27
	(0.35)	(0.50)	(0.21)	(0.24)	(0.44)

Standard Deviation in parenthesis

5.4.2 Determinants of livelihood strategies

We used a multinomial logit (MNL) regression to assess the capital endowment and livelihood strategies in 2015/16 (Table 5.2). The annual farming strategy is the base category for MNL regression. We used variables for human, financial and natural capital.

Households headed by older people were more likely to be involved in self-employment/annuals, salaried employment/annuals and perennial/annual farming compared to the annual farming only strategy. Older household heads may have accumulated money to start a business, and they may have planted perennial crops throughout the years. Over the years, the government of Uganda has been promoting and distributing perennial crops such as coffee, fruit trees, bananas, and cocoa (GoU, 2016).

The household head's education was used as a proxy for human capital. Household heads with education above primary level are more capable of engaging in self-employment/annuals, casual employment/annuals and salaried employment/annuals compared to the annual farming only strategy. Salaried employment/annuals required a higher education level, followed by casual employment/annuals and self-employment/annuals. Non-farm employment requires knowledge and skills (Barrett, Bezuneh, et al., 2001; Nielsen et al., 2013). In Uganda, since rural households have low literacy levels, they may not have the required skills and knowledge for non-farm employment.

Households with fewer members in the households were more likely to engage in perennial/annual farming compared to the annual farming only strategy. These households might have adult children as older household heads participated in a perennial/annual strategy. For households with an additional member, the relative risk of choosing annual farming to perennial/annual farming would be expected to decrease by a factor of 0.952, keeping other factors constant. The higher the dependency ratio, the less likely a household was involved in self-employment/annuals; however, this effect is very small. Households with more dependants have more domestic obligations, which may hinder their participation in off-farm employment.

There is variation in livelihood strategies choices in the selected districts. Households located in Masindi, Tororo and Iganga districts were less likely to be involved in self-employment/annuals and perennial/annual farming strategies than in annual farming only strategy compared to their Hoima district counterparts. Casual employment/annuals is more likely to be undertaken by households located in Masindi district. This shows that location is an important factor when choosing a livelihood strategy. Different districts are targeted when promoting different crops, for example, Iganga and Masindi were targeted for maize (GoU, 2019).

Table 5.2: Multinomial Logit Regression results: Determinants of Livelihood Strategies, 2015/16

	Self-employment/ annuals	Casual employment/ Annuals	Salaried employment/ annuals	Perennial/annual farming
Human capital				
Age of the household head (years)	1.027***	0.990	1.018**	1.029***
	(0.005)	(0.009)	(0.007)	(0.004)
Gender of the household head (1=Male, 0=Female)	1.370	1.563	0.822	1.033
	(0.297)	(0.545)	(0.297)	(0.180)
Education (1=above primary education; otherwise=0)	1.942***	2.217***	3.469***	1.195
	(0.278)	(0.520)	(0.738)	(0.135)
Household size	1.037	0.985	1.007	0.952**
	(0.025)	(0.043)	(0.035)	(0.019)
Dependency Ratio	0.993**	0.0.993	0.991*	0.999
	(0.003)	(0.006)	(0.005)	(0.003)
Financial capital				
Access to credit	1.086	1.223	1.098	0.941
	(0.112)	(0.214)	(0.165)	(0.086)
Natural capital				
Land owned (acres)	1.001	1.007	1.002	1.004
	(0.007)	(0.009)	(0.010)	(0.005)
Location				
Household accessed by tarmac or murram road	1.371	1.414	0.776	1.021
	(0.324)	(0.555)	(0.215)	(0.170)
District; Masindi=1, otherwise=0	0.511***	2.561***	1.105	0.620***
	(0.107)	(0.823)	(0.298)	(0.097)
District; Tororo=1, otherwise=0	0.667**	1.310	1.115	0.563***
	(0.131)	(0.466)	(0.305)	(0.090)
District; Iganga=1, otherwise=0	0.645**	0.627	0.627	0.619***
	(0.123)	(0.261)	(0.186)	(0.095)
Constant	0.052***	0.043***	0.068***	0.287***
	(0.024)	(0.033)	(0.0445)	(0.103)
Wald chi2(44) = 221.92				
Prob > chi2 = 0.0000				
Pseudo R2 = 0.0438				
N=2,035				

Base outcome: annual crop farming. *** p=0.01 ** p=0.05 * p=0.1. Standard errors in parentheses

5.4.3 Income levels across livelihood strategies

Table 5.3 presents the average per capita income from each livelihood strategy in both years. It clearly shows that all strategies are diverse; although farmers categorised under the annuals strategy allocate by far most of their land and labour resources to annual cropping (see Table A5.1), even these farmers earn income from other activities on average. The annuals strategy generated the lowest income in both years, followed by the perennials/annuals strategy. Interestingly, annual crop income is not particularly high for the farmers in the annuals strategy, which indicates that to make more income, households need to get involved in other activities, particularly off-farm activities. From the qualitative data, farmers sell their products at the farmgate or at the local markets. Due to an urgent need for cash and lack of storage facilities, most farmers sell their produce immediately after harvest, when prices are low. Salaried employment/annuals had the highest mean per capita income in 2013/14, followed by self-employment/annuals and casual employment/annuals. In 2015/16, casual employment/annuals and salaried employment were the leading remunerative strategies, with almost equal average incomes, relatively closely followed by self-employment/annuals. These findings are in line with past evidence that shows that livelihood outcomes (income) are associated with a livelihood strategy (Jansen et al., 2006; Jiao et al., 2017; Nielsen et al., 2013; Van den Berg, 2010; Walelign et al., 2017). Non-farm income sources are important in improving incomes and strengthening resilience (Barrett, Bezuneh, et al., 2001; Carter & Barrett, 2006; Ellis, 1998).

Table 5.3: Household income components across livelihood strategies (in Ugandan Shillings per capita)

	All	Self-employment / annuals	Annuals	Casual employment /annuals	Salaried employment / annuals	Perennials/ annuals
2013/14						
Total income	737,197	1,041,155	508,385	1,009,016	1,629,213	793,801
Income shares						
Farm income	0.53	0.32	0.67	0.35	0.30	0.65
Annuals	0.34	0.25	0.55	0.19	0.17	0.23
Perennials	0.18	0.08	0.12	0.16	0.12	0.42
Off-farm income	0.47	0.68	0.33	0.65	0.70	0.35
Salary	0.13	0.05	0.03	0.03	0.61	0.10
Casual wages	0.06	0.01	0.06	0.49	0.01	0.05
Business	0.29	0.62	0.23	0.13	0.08	0.20
2015/16						
Total income	908,059	1,164,719	761,229	1,349,541	1,321,495	865,250
Income shares						
Farm income	0.66	0.51	0.73	0.46	0.45	0.78
Annuals	0.43	0.28	0.57	0.30	0.28	0.39
Perennials	0.23	0.23	0.16	0.16	0.17	0.39
Off-farm income	0.34	0.49	0.27	0.54	0.55	0.22
Salary	0.12	0.13	0.05	0.22	0.48	0.06
Casual wages	0.05	0.03	0.05	0.23	0.01	0.03
Business	0.17	0.33	0.17	0.09	0.06	0.13

Table 5.4 compares the per capita income distributions across the livelihood strategies using stochastic dominance. Like the ranking of average incomes, the non-farm strategies dominated the farm strategies, with perennial farming dominating annual farming. A salaried employment/annuals strategy was the dominant strategy in 2013/14, while in 2015/16 dominance was comparable for all three non-farm strategies. This confirms our earlier finding that off-farm employment is attractive in the rural Eastern and mid-western Uganda and that to achieve higher per capita income, a household needs to engage gainfully in off-farm employment in addition to farming.

Table 5.4: Stochastic dominance between livelihood strategies.

Livelihood strategy	2013/14		2015/16	
	Dominant	Dominated	Dominant	Dominated
Non-farm strategies				
Self-employment/annuals	2	1	2	1
Salaried employment/annuals	4	0	2	0
Casual employment/annuals	2	1	2	0
Farm strategies				
Annuals	0	4	0	4
Perennials/annuals	1	3	1	3

Dominant strategy has a better outcome than the alternative strategies, while dominated strategy has a worse outcome than alternative strategies.

5.4.4 Livelihood strategy dynamics

While the distribution of households over the different livelihood strategies was similar for the two periods, more than half of the individual households switched strategies. The transition matrix in Table 5.5 five shows that the most stable livelihood strategies were annual farming and perennial/annual farming, with 56 percent and 41 percent of households assigned to this strategy in 2013/14 re-assigning to the same strategy in 2015/16. For the remaining strategies, only about 20-30 percent of households maintained their previous strategy. About 43 percent of households shifted from self-employment/annuals to annual farming, and 29 percent shifted to perennial/annual farming. About 12 percent and 25 percent who practised annual farming moved to self-employment/annual and perennial/annual farming, respectively.

The frequent shifts from more remunerative diversified strategies back to specialised annual farming may seem surprising. Yet many of the salaried jobs, especially the unqualified jobs, have low job security. Similarly, like elsewhere in rural Africa, non-farm self-employment involved mainly activities that were easy to enter and exit (Nagler and Naude, 2017). Shifting of households from and to a livelihood strategy may be caused by the necessity to cope and manage risks, or changes in opportunities (Barrett, Bezuneh, et al., 2001; Dorward et al., 2001). For example, during FGDs, participants indicated that in the case of a negative shock to their agricultural production, people opt to participate in casual labour to get food. Also, a specific household head was employed as a policeman until 2014 but became a businessman thereafter (farmer interview, 2017). As shown before, on average, some income was earned for each activity in all livelihood strategies, so that a switch in strategy may involve a re-allocation of resources between existing activities as well as the introduction/ceasing of an activity. Shifting is thus not necessarily an indication of a dramatic change.

The share of households engaged in each strategy is similar for the two periods, and households revert to farm-focused strategies after first being engaged in a relatively profitable mixed farm/off-farm strategy just as easily as the other way around. Self-employment often involves short-term small-scale trading (FGD, 2017) and casual employment obviously involves short-term contracts. Therefore, returns may vary strongly between years depending on availability of working capital and employment opportunities. Even opportunities for perennial cropping and salaried employment are not stable. Dzanku (2015) observed a similar instability of livelihood strategies in Ghana.

Table 5.5: Livelihood strategies transition matrices for all the sampled households (row shares)

2015/16 2013/14	Self-employment/ annuals	Annual farming	Casual employment/ annuals	Salaried employment/ annuals	Perennials/ annuals
Self-employment/annuals	0.21	0.43	0.04	0.05	0.29
Annual farming	0.12	0.56	0.04	0.04	0.25
Casual employment/annuals	0.20	0.39	0.22	0.10	0.09
Salaried employment/annuals	0.20	0.29	0.07	0.33	0.11
Perennials/annuals	0.12	0.37	0.03	0.07	0.42

Pearson chi2(16) = 344.4089 Pr = 0.000

5.4.5 Crop production trends across livelihood strategies

As crop production is an important component for all livelihood strategies, we further zoom in on this activity. Most of the households practice crop diversification, which can be beneficial as it enhances crop production and resilience (Makate et al., 2016; Mango et al., 2018). In each strategy, households cultivate on average between 6 and 10 crops per cropping year (Table 5.6). The number of crops was highest for the perennial/annual farming strategy. Surprisingly, it was relatively low for the annuals strategy, although differences with the off-farm strategies were small.

Maize, beans and cassava are the most cultivated crops grown by more than 75 percent of households. About half of the interviewed households cultivated bananas, groundnuts and sweet potatoes, and about 20 percent cultivated rice and coffee. Cassava, bananas and sweet potatoes serve as a food security crop when there is crop failure or scarcity because they are drought-resistant crops (farmer interview, 2017). Such drought-resistant crops are often used for subsistence and to smoothen consumption (Moniruzzaman, 2015). The share of farmers growing each crop is relatively similar for the two years and the strategies, except for coffee, which is grown more by households with the perennial/annuals strategy. The proportion of farmers who grew fruit trees doubled in 2015/16. The government of Uganda has been promoting fruit production through provision of extension services and planting materials for apples, oranges and pineapples (MAAIF, 2019). In addition to bananas, coffee and fruit trees, other perennial crops grown (not included in the table) are cocoa and sugarcane. Hence, rural households grow similar crops despite allocating a substantial share of their labour to off-farm employment.

While the total cultivated area[5] increased somewhat between the survey periods, the proportions of land allocated to the different crops are similar between strategies and year, except for the perennial strategy. Households allocated about 34 percent of their cultivated land to maize. Legumes such as beans are mainly intercropped with maize and sugarcane or cassava (farmer interview, 2017). This is in line with findings from FEWSNET (2017b), where maize and beans are the most cultivated crop in terms of area

[5] Other perennials include fruit trees rarely planted on one plot; they are scattered or within plots under annual crops. Total area cultivated under these crops may be exaggerated, exaggerating the total area cultivated. Yield and crop share for other annuals and perennials is not included in the table.

planted and volume produced with Eastern and Western regions. However, some households stopped cultivating maize and opted for other crops, e.g. a farmer in Hoima district stopped planting maize in 2015 and opted for sorghum, rice and soya bean (farmer interview, 2017). Households adopting the perennial/annual strategy allocated about 50 percent of the cultivated land to perennial crops.

Additionally, yields and shares of produce sold to the market did not differ much between livelihood strategies (Table 5.7). In 2015/16, there was an increase in yields for beans, bananas, cassava, groundnuts, sweet potatoes and coffee but a decrease in rice yields. Less than half of the harvested crops were sold, except for coffee and rice. Rice is mostly grown as a cash crop because it is not traditionally consumed by rural households in Uganda. In 2015/16, the proportion sold increased for all crops except maize. From qualitative data, a farmer said, “I produce crops such as maize, beans and groundnuts for sale, while sweet potatoes, cassava, rice, bananas, vegetables and cowpeas are for food,” (farmer interview, 2017). These findings indicate that most households focus on semi-subsistence farming rather than commercialised farming.

Table 5.8 presents data on the use of improved seeds for maize and beans. Maize and beans are major crops in the study area that are important for both consumption and cash income and have received relatively high levels of investment from the government and development agencies, for example in the development and promotion of improved seeds. Despite their efforts, most farmers do not use certified seeds. We expected farmers specialising in annual cropping to cultivate more improved varieties. However, differences between livelihood strategies are small and inconsistent between the two years. Perhaps the limited profitability of annual farming limited the capability of or interest in investing in improved seeds. The casual employment/annuals and salaried employment/annuals had the highest users of improved varieties in 2013/14. In 2015/16, the annual farming strategy was second in usage of improved maize seeds. Salaried employment/annuals allocated the highest percentage of their land to improved maize in 2013/14, while the casual employment/annuals allocated the highest proportion to improved maize.

Table 5.6: Crop production: Type of crops and acreage planted per crop

	Sample Mean	Self-employment/ annuals	Annuals	Casual employment /annuals	Salaried employment/ annuals	Perennials/ annuals	Sample Mean	Self-employment/annuals	Annuals	Casual employment /annuals	Salaried employment/ annuals	Perennials / annuals
Number of crops	7	6	7	6	7	9	8	8	8	8	9	10
Proportion of farmers that planted the specified crop (main crops only)												
Maize	0.95	0.96	0.96	0.95	0.94	0.92	0.91	0.89	0.94	0.89	0.94	0.86
Beans	0.88	0.88	0.89	0.85	0.91	0.87	0.85	0.81	0.86	0.79	0.88	0.84
Cassava	0.76	0.72	0.79	0.76	0.73	0.75	0.8	0.75	0.83	0.8	0.82	0.74
Rice	0.21	0.21	0.24	0.2	0.2	0.15	0.24	0.22	0.27	0.18	0.2	0.22
Groundnut	0.53	0.47	0.54	0.41	0.6	0.56	0.49	0.49	0.49	0.48	0.6	0.47
Sweet potatoes	0.55	0.57	0.54	0.51	0.63	0.54	0.64	0.63	0.64	0.66	0.64	0.62
other annuals	0.44	0.41	0.47	0.39	0.48	0.39	0.41	0.46	0.43	0.38	0.38	0.36
Bananas	0.55	0.49	0.46	0.48	0.53	0.81	0.64	0.69	0.54	0.65	0.65	0.79
Coffee	0.26	0.2	0.18	0.22	0.27	0.52	0.34	0.36	0.28	0.21	0.34	0.48
Other perennials	0.56	0.41	0.45	0.56	0.5	0.93	0.85	0.87	0.77	0.78	0.84	1
Total area	7.81	6.87	7.05	7.36	8.37	10.21	9.42	9.51	8.99	7.54	10.32	10.23
Proportion of acreage planted per crop												
Maize	0.31	0.34	0.37	0.35	0.32	0.17	0.36	0.35	0.45	0.38	0.32	0.25
Beans	0.13	0.16	0.15	0.16	0.13	0.09	0.11	0.11	0.12	0.12	0.11	0.09
Cassava	0.10	0.10	0.12	0.09	0.11	0.06	0.09	0.09	0.10	0.12	0.09	0.07
Rice	0.03	0.03	0.04	0.04	0.03	0.01	0.03	0.03	0.04	0.03	0.02	0.02
Groundnut	0.06	0.06	0.07	0.04	0.07	0.04	0.04	0.05	0.05	0.05	0.06	0.03
Sweet potatoes	0.04	0.06	0.05	0.04	0.05	0.03	0.04	0.04	0.05	0.04	0.04	0.04
Other annuals	0.08	0.08	0.09	0.08	0.08	0.05	0.05	0.06	0.06	0.05	0.06	0.04
Bananas	0.04	0.04	0.03	0.03	0.05	0.08	0.04	0.04	0.02	0.04	0.05	0.06
Coffee	0.03	0.02	0.01	0.01	0.02	0.06	0.02	0.03	0.01	0.01	0.02	0.05
Other perennials	0.17	0.09	0.06	0.15	0.15	0.39	0.20	0.21	009	0.17	0.23	0.36

Table 5.7: Crop production: Yields and share of crop sold

	2013/14						2015/16					
	Sample mean	Self-employment/annuals	Annuals	Casual employment /annuals	Salaried employment/annuals	Perennials/ annuals	Sample mean	Self-employment/annuals	Annuals	Casual employment /annuals	Salaried employment/ annuals	Perennials / annuals
Yields (kg/acre) (for those that planted)												
Maize	447	417	432	621	419	484	356	307	328	342	400	429
Beans	172	173	162	227	151	191	197	220	180	196	156	226
Cassava	745	692	686	748	705	937	991	1335	1042	964	807	764
Rice	644	877	591	706	542	630	444	461	461	315	340	434
Groundnut	498	6871	470	403	820	444	632	353	792	1155	272	507
Sweet potatoes	1409	1139	1361	1018	1687	1702	1578	1528	1634	1271	1450	1585
Bananas	1893	1424	2168	1388	1695	1801	3821	3493	4995	3694	3698	2593
Coffee	341	377	363	364	423	300	589	1022	641	699	330	406
Share of crop sold (for those that harvested)												
Maize	0.40	0.40	0.42	0.33	0.36	0.39	0.34	0.32	0.36	0.33	0.32	0.31
Beans	0.24	0.24	0.25	0.23	0.21	0.23	0.25	0.24	0.26	0.24	0.24	0.25
Cassava	0.10	0.13	0.11	0.08	0.11	0.09	0.16	0.15	0.17	0.13	0.17	0.13
Rice	0.62	0.64	0.63	0.63	0.42	0.61	0.64	0.60	0.66	0.53	0.70	0.63
Groundnut	0.32	0.31	0.32	0.30	0.29	0.33	0.33	0.27	0.35	0.34	0.37	0.31
Sweet potatoes	0.06	0.06	0.07	0.02	0.04	0.05	0.07	0.07	0.07	0.05	0.11	0.07
Bananas	0.15	0.15	0.14	0.12	0.11	0.17	0.16	0.15	0.15	0.14	0.17	0.18
Coffee	0.91	0.88	0.94	1.00	0.88	0.89	0.99	0.98	0.98	1.00	1.00	0.99

Table 5.8: Crop production: Certified maize and bean varieties

	2013/14						2015/16					
	Sample mean	Self-employment/annuals	Annuals	Casual employment /annuals	Salaried employment/annuals	Perennials/ annuals	Sample Mean	Self-employment/annuals	Annuals	Casual employment /annuals	Salaried employment/ annuals	Perennials/ annuals
Proportion of households that planted certified maize												
Maize	0.25	0.26	0.24	0.29	0.31	0.26	0.38	0.31	0.43	0.45	0.41	0.31
Bean	0.04	0.04	0.03	0.01	0.04	0.06	0.15	0.13	0.17	0.18	0.12	0.15
Land under certified maize (acres)												
Maize	0.60	0.55	0.62	0.66	1.01	0.48	0.89	0.83	1.07	1.15	0.88	0.54
Bean	0.03	0.05	0.02	0.01	0.04	0.04	0.14	0.14	0.15	0.09	0.10	0.12
Proportion of land under certified maize (for those that planted) N=3,788												
Maize	0.18	0.18	0.16	0.20	0.21	0.20	0.20	0.19	0.21	0.28	0.24	0.17
Bean	0.02	0.03	0.02	0.01	0.03	0.04	0.18	0.17	0.19	0.14	0.21	0.16

5.5 Conclusions

This paper uses household panel surveys and qualitative data to analyse livelihood strategies and their dynamics in rural households in Uganda. All households participated in annual farming and many had perennial crops and non-farm activities, but the importance of these activities differed greatly between households and, for individual households, between years. The study identifies five livelihood strategies, namely self-employment/annuals, annuals, casual employment/annuals, salaried employment/annuals and perennials/annuals. Despite the observed instability of household-level livelihood trajectories, the overall distribution of households over the strategies did not change much between the two years. However, there was a slight increase in households that participated in the perennials/annuals strategy at the cost of the annual farming strategy due to a government programme that promoted the cultivation of coffee and fruit trees (NAADS, 2018).

The most grown annual crops were maize, beans and cassava. Common perennial crops were bananas, fruit trees and coffee. The proportion of land allocated to each crop, yield and share of crop sold did not differ much between livelihood strategies, except for the perennial strategy. The proportion of land allocated to improved varieties is small, despite the importance of annual farming for all households in the study area. Contrary to other studies that showed that non-farm income has a positive effect on the improved seed use (Amare & Shiferaw, 2017; Mathenge et al., 2015; Pfeiffer et al., 2009), we do not see the same connections and, similar to Chikwama (2010), we thus do not find that off-farm employment contributes to farm investment..

Our results show that there are several factors that influence or constrain the choices of livelihood strategies. These factors are education, age, household size, dependency ration and location of the household. This suggests that there are entry barriers to the remunerative off-farm employment. Households with better education would be more capable of engaging in knowledge- and skill-based activities and non-farm opportunities (Barrett, Reardon, et al., 2001; Nielsen et al., 2013). Age is associated with the accumulation of resources such as perennial crops and availability of cash to start a business. Older people in salaried employment may also decide to move closer to their rural homes ahead of retirement. The results show that households with older heads are more likely to be engaged in self-employment/annuals, salaried employment/annuals and perennial/annual farming compared to the annual farming only strategy. Household size affected the probability of engaging in the perennial/annual strategy negatively while the dependency ratio affected the probability of engaging in self-employment/annuals negatively. Location was also an important factor in choosing a livelihood strategy. Households in Hoima district were more likely to be involved in self-employment/annuals and perennials/annuals strategies compared to the annual farming only strategy, while households located in Masindi district were more likely to be involved in casual employment/annuals compared to the annual farming only strategy.

Households that diversify their activities through non-farm employment in any given year had higher incomes, hence strengthening resilience. The annual farming strategy and perennials/annuals strategy had the lowest income in both years and the annual farming strategy was dominated by all other strategies. As non-farm employment strategies had higher income, diversification helped to improve incomes. The transition matrices show that individual households switched between strategies, with households moving in and out of the more remunerative non-farm strategies. The most stable livelihood strategies are annual farming followed by perennials/annuals, with about half of the participants remaining in the strategies. Households in annual farming strategy especially moved to perennial/annual farming and vice versa. Only one fifth to one third of households in the non-farm strategies remained in the same strategy in both survey periods, with the largest share reverting to annual farming. There are two conditions for moving into non-farm employment – growth in the non-farm sector and accessibility to those jobs (Haggblade et al., 2010). The qualitative study reveals that farmers shift to different strategies, such as self-employment and casual employment, when there is an opportunity and to meet their immediate needs, such as school fees. Overall, our findings indicate that the non-farm strategies boost household income, but this does not necessarily mean that households will not shift to a less remunerative strategy. Hence, there is need for a policy to improve not only access to, but also the stability of, the non-farm activities that are available to the rural households to supplement income. However, it is important to note that annual farming forms the mainstay of income of about half of the households and is an important secondary income source for the rest. Therefore, policies to improve agricultural productivity are still needed.

Since our study is based on two cropping years, it may not capture the long-term transition of livelihood strategies. Long-term surveys may help in capturing the dynamics of livelihood strategies and incomes sources. Our findings are limited to a single country and time period when the surveys were conducted. Further research on major crops should be conducted to provide patterns of adoption. Additional research is recommended into the re-investment of off-farm income in agriculture through purchase of input which may impact farm and off-farm activities in the long run.

Appendix

Table A5.1: Cluster analysis results for livelihood strategies.

Variable	All	Self-employment /annuals	Annual farming	Casual wages/annuals	Salaried employment /annuals	Perennial/annual farming
2013/14						
Proportion		0.15	0.53	0.04	0.06	0.22
Labour						
Salaried	0.03 (0.003)	0.004 (0.001)	0.001 (0.001)	0.01 (0.01)	**0.51** **(0.02)**	0.01 (0.003)
Casual wages	0.02 (0.002)	0.002 (0.001)	0.001 (0.001)	**0.52** **(0.02)**	0.00 (0.00)	0.01 (0.002)
Self-employment	0.10 (0.004)	**0.54** **(0.01)**	0.01 (0.001)	0.06 (0.02)	0.06 (0.01)	0.03 (0.004)
Farming	0.85 (0.006)	**0.45** **(0.01)**	**0.99** **(0.001)**	**0.41** **(0.02)**	**0.44** **(0.02)**	**0.95** **(0.01)**
Land shares						
Annual crop	0.80 (0.005)	**0.86** **(0.01)**	**0.90** **(0.003)**	**0.82** **(0.02)**	**0.82** **(0.02)**	**0.50** **(0.01)**
Perennial crop	0.20 (0.005)	0.14 (0.01)	0.10 (0.003)	0.18 (0.02)	0.18 (0.02)	**0.49** **(0.01)**
2015/16						
Proportion		0.14	0.48	0.04	0.06	0.27
Labour						
Salaried	0.06 (0.004)	0.03 (0.01)	0.01 (0.002)	0.02 (0.01)	**0.69** **(0.02)**	0.01 (0.002)
Casual wages	0.02 (0.002)	0.01 (0.003)	0.001 (0.00)	**0.45** **(0.02)**	0.003 (0.002)	0.01 (0.002)
Self-employment	0.08 (0.004)	**0.47** **(0.01)**	0.01 (0.001)	0.05 (0.01)	0.01 (0.004)	0.01 (0.002)
Farming	0.85 (0.006)	**0.49** **(0.01)**	**0.98** **(0.002)**	**0.48** **(0.02)**	**0.30** **(0.02)**	**0.97** **(0.004)**
Land shares						
Annual crop	0.75 (0.004)	**0.72** **(0.01)**	**0.88** **(0.003)**	**0.79** **(0.02)**	**0.73** **(0.02)**	**0.55** **(0.01)**
Perennial crop	0.25 (0.004)	0.28 (0.02)	0.12 (0.003)	0.21 (0.02)	0.27 (0.02)	**0.45** **(0.01)**

Standard errors in parentheses

6

Chapter 6

Synthesis

Chapter 6

Synthesis

6.1 Introduction

In Sub-Saharan Africa, promotion of rural economic development should be carefully considered. With slow growth in per capita income and dwindling cultivation area due to population pressure, smallholder farmers need to use modern technologies to raise agricultural output or diversify their livelihood strategy. To date, many smallholder farmers in Africa are not using modern technologies or improved agronomic management practices. It is important to note that there is heterogeneity in the use of modern technologies across African countries (Christiaensen, 2017; Sheahan & Barrett, 2017). Use of improved technologies has been relatively low in Uganda compared to countries such as Kenya, Ethiopia and Malawi. Increases in agricultural productivity are important to rural smallholder farmers because agriculture is the main activity. Productivity gains can be attained by improved technologies like enhanced crop varieties and improved crop husbandry management practices. Improved technologies contribute directly to development through increased production for home consumption, increased marketable surplus, and indirectly through employment opportunities and increased wages in agriculture and non-agricultural sectors.

Agricultural productivity differentials between research stations and farmer fields are huge (Tittonell & Giller, 2013). Modern technologies applied at the station often do not reach farmers, resulting in low use and low productivity of crop production. Information and learning constraints are among the main reasons for low adoption (Foster & Rosenzweig, 1995; Shikuku et al., 2019). Development agencies such as the Alliance for a Green Revolution in Africa (AGRA) and national governments have focused on the promotion of new technologies by supporting information dissemination and marketing, hoping that smallholder farmers will use them to increase their yields and incomes (Lambrecht et al., 2014). However, not all these efforts have been equally effective.

To induce use of improved technologies, both successful and unsuccessful interventions need to be studied. Often, only success stories and lessons learned are reported, ignoring the unsuccessful cases. Studying the unsuccessful interventions may provide insights in the challenges that led to the failure, which will reduce the chances of making the same mistakes in the future. The successes of interventions leading to adoption of technology should be carefully interpreted since they can be short-term, partial or inconsistent, depending on the households' current condition. Continued use of technologies is far from inevitable and disadoption is common among smallholder farmers (Bizoza, 2014; Moser & Barrett, 2003, 2006; Neill & Lee, 2001; Sanou et al., 2017; Tura et al., 2010; Wakeyo & Gardebroek, 2015). Since adoption of technologies is not straightforward, measuring its impact over time is a challenging process.

African smallholder households remain poor because they mainly depend on low-production agriculture with only about 30 percent of income coming from non-farm activities on average (Davis et al., 2017). Households diversify their activities into a combination of farm and non-farm activities either to survive or to improve their standard of living. According to Davis et al. (2017), rural households participating in non-farm activities are better off, and the non-farm income allows them to afford improved agricultural technologies. Policies are necessary on how to improve smallholder households' livelihoods through increased and continued technology diffusion, successful agricultural programs or engagement in non-farm activities.

Given the issues discussed above, this thesis explores and analyses a case study where a new technology was introduced to farmers through demonstration plots with the expectation of knowledge and technology diffusion. The thesis not only sheds light on the interactions among the actors involved in this process of diffusion (farmers, demo hosts, seed company officials/extension agents) but also the constraints that led to low awareness and uptake of the technology. The thesis provides insights in adoption dynamics and the determinants of adoption and disadoption as well as in the effects of adoption of improved maize varieties on productivity and incomes. In addition, livelihood strategies, determinants of livelihood choices, the transitions between strategies, and their outcomes were studied. The analysis was carried out using household survey data and qualitative data collected from farmers and key informants. The main messages of the thesis are: (i) incorporating farmers' needs and wishes in information dissemination programs is important for effective knowledge diffusion and technology adoption; (ii) technology adoption is not a one-time decision; (iii) social, environmental and didactic learning must work together for successful learning and technology adoption; in Eastern and Mid-Western Uganda (iv) disadoption of improved seeds is common due to factors such as procrastination and the presence of low quality seeds on the market; (v) the adoption of improved maize seeds increases productivity but does not result in higher maize incomes per hectare; (vi) while all households engage in annual crop production, nonfarm diversification is key to improving income, though switches to more remunerative, diversified livelihood strategies are often not structural.

This thesis used quantitative and qualitative data collected in four districts: Masindi and Hoima in mid-western region, and Tororo and Iganga in eastern region. Specifically, Chapter 2 used data from areas where a seed company promoted new maize and bean seed using demonstration plots integrated with field days. The remaining chapters (3, 4 and 5) used the survey data collected in the entire study area. Chapters 3 and 4 focus on the adoption of improved maize varieties. Chapter 3 focuses on the factors affecting decisions to use improved maize varieties and changes to adoption decisions made by smallholder farmers each year using survey data. We further investigate the changes in management practices when using improved varieties on farmers, using qualitative data. Chapter 4 studies the effect of adopting certified maize varieties on productivity and incomes. Finally, chapter 5 focuses on the livelihood strategies and dynamics among the smallholder farmers in Uganda, using quantitative and qualitative data.

6.2 Methods

In this thesis, we used a mixed method approach that integrates quantitative and qualitative methods. These studies are not common, although economic researchers are encouraged to use mixed methods to enrich the economic evaluations with context-specific information (Dopp et al., 2019). Combining quantitative and qualitative methods helped us to not only validate our results by triangulating data but also to understand the outcomes better than if we had used a single method. We were able to capture complexities of the technology dissemination and adoption. Qualitative method helped us to integrate contextually grounded stories to explain and strengthen the quantitative results in Chapters 2 and 3. In Chapter 2, we were able to understand the reasons for low awareness and adoption among the farmers. Consequently, we explored the farmers' perceptions and experiences about information dissemination and demonstration plots. In chapter 3, we were able to capture the management practices used for different maize varieties.

The use of mixed methods enables the researcher to gain insights into complex issues (Hesse-Biber, 2008). In this thesis, we provide rich insights that a single method could not provide, although it was challenging to satisfy the requirements of quantitative and qualitative methods at the same time. Consequently, integration of the two methods required more efforts than when using a single method. Many researchers prefer using single studies (either quantitative and qualitative) and report the results separately. When mixed methods is used, it is challenging to convince quantitative researchers that statistical inferences are valid and qualitative researchers that the complex process has been thoroughly captured. Morgan and Hoffman (2021) found out that quantitatively driven mixed methods are widely used compared to qualitatively driven methods. In this thesis, the mixed method is predominantly quantitatively driven, helping to identify the farmers that were subsequently studied in depth using qualitative methods.

In what follows, I discuss the main findings from chapters 2 through 5, policy implications and suggestions for future research.

6.3 Discussion of crosscutting issues in the thesis, policy implications and future research

6.3.1 Learning and adoption of newly introduced improved varieties

In chapter 2, demonstration plots integrated with field days and training and visits of information disseminators -in this case demonstration hosts- were used to disseminate knowledge and technology. After the training, the demo hosts would share the information with other farmers. However, the knowledge and adoption of the promoted technologies was not effectively spread. The lack of success of the program was not exceptional, as Kondylis and Mueller (2013) show that there are both successes and failures in the usage of demonstration plots in technology diffusion, depending on the circumstances. Knowledge diffusion was high among direct acquaintances of the information disseminators (demo hosts), such as those who were members of the same farmer group, but generally low among others.

Unconducive conditions of the demonstration plots such as poor publicity, poor visibility and unco-operative host farmers were among the factors that contributed to the constrained learning process.

Social interactions are key to learning (BenYishay & Mobarak, 2019; Stone, 2007). These interactions depend on the position of the person influencing the learning and the circumstances under which the learning process took place. This thesis provides additional insights in two ways; first, I study how social learning affects knowledge and technology. Chapter 2 shows that knowledge levels were higher in villages where the demo hosts was a group member with direct contact and close interactions with other farmers compared to villages where there were no/minimal interactions between the demo host and farmers. This is in line with findings that prior existing relationships and farmer groups are important in the learning process (Ainembabazi et al., 2017; BenYishay & Mobarak, 2019). Additionally, demo hosts in groups could have been viewed to have more similar characteristics and similar agricultural conditions by group members compared demo hosts not in groups, which was found to be important by Bandiera and Rasul (2006); BenYishay and Mobarak (2019); Munshi (2004) and Stone (2016). There was little learning effect in general resulting in low knowledge among farmers in all districts. This could have been influenced by a lack of incentives to motivate the demo hosts to share the information, as indicated by Shikuku et al. (2019).

Involvement of farmers in demonstration plots and on-farm experiments, and frequency of interactions between information disseminators and farmers may influence the learning effects. In chapter 2, the seed company officials assumed that demo hosts would share the information and signposts would relay the correct message. However, this did not happen in the studied case study, which confirms the results of (Kondylis & Mueller, 2013) where there was little effect at community level where the trained contact farmers trained other farmers. Local farmers were not interested in learning about the seeds because their views and opinions were not considered when the demo hosts and location of agro-dealers were being selected. Involving the community in the selection of information disseminators, such as demo hosts, may increase trust in the motive and competence (Buck & Alwang, 2011). Although social learning is important for initial adoption, chapter 3 indicates that adoption is not a permanent decision for individual farmers.

Second, the thesis studies social learning in itself. In chapter 2, we establish that different types of interactions and learning mechanisms (such as social, environment and didact) work together for successful technology diffusion. Social learning may not take place as expected if environmental learning is hindered. Environmental learning takes place through observation and interpretation of crop performance and its benefits (Stone, 2016). Chapter 2 reveals that environmental learning about new technologies was hindered due to several reasons. First, farmers' lack of interest and minimal interactions with demo hosts due to uncooperative demo hosts and farmers' perception that the seed company favoured some demo hosts limited observation of crop performance. Second, some demonstration plots were not managed properly resulting in poor crop performance. Third, willing farmers were not able to plant the new seeds on their farms due to inaccessibility, unavailability and unaffordability of seeds, e.g. due to long distances between farmers and agro-dealers and high seed prices limiting observation of the crop in their own farms. However, the findings of chapters 2 and 3 show that even with successful environmental learning (for the case of demo hosts in chapter 2), factors such as procrastination in buying the seed and inaccessibility of seed affect the adoption process of improved technologies.

Didactic learning may affect the social and environmental learning due to didacts' interests which may differ with farmers' interests e.g. in India (Stone, 2016). Didacts have their own interests (marketing their commodities) which are different from farmers' interests (increasing productivity and incomes). In chapter 2, didacts included commercial agents like seed company and agro-dealers whereby the seed company was involved in setting up demonstration plots, training farmers during field days and training the demo hosts each season for two years. Agro-dealers were involved in training during field days and stocked up the seed. The seed company's assumption that information would freely flow from the demo hosts to other farmers was misplaced. The information flow was affected by refusal of farmers to seek the information from untrusted demo hosts and unwillingness of demo host to share the information (chapter 2). Provision of incentives to the information and technology disseminator would have helped the spread of information and knowledge about the promoted technology (Shikuku et al., 2019).

The information and technology diffusion process encountered some challenges which hindered the smooth running of the demonstration plots and adoption of the new seeds (chapter 2). This in turn affected the social and environmental learning as discussed above. Further, chapter 2 reveals that the seed company made little effort to ensure the smooth running of demonstration plots, timely announcements about field days, and timely delivery of the new seeds. Poorly managed demonstration plots and late delivery of the seeds negatively affected environmental learning, while low participation in demonstration plots and field days negatively affected both social and environmental learning. Although not covered in this study, in situations where the new seed was not available, the agro-dealers could advise the farmers on the alternative seeds, thereby undermining the environmental learning. This happened in India, where farmers were advised to grow an alternative cotton variety (Stone, 2007, 2016).

6.3.2 Adoption, disadoption and effect of adoption of improved varieties on productivity and income

Increased knowledge does not guarantee increased adoption of improved technologies. In some instances where adoption has taken place, continued adoption is not guaranteed, as shown in chapters 2 and 3. When selecting technologies, farmers evaluate their suitability (Emerick et al., 2016) and the quality of the agro-inputs required (Ashour et al., 2017; Bold et al., 2017). The expected benefits may not meet farmers' expectations (see Chapter 4 where maize income per hectare did not increase with use of improved varieties), or may not meet the cost of buying the seed, or the costs/benefits may have changed over time (Kijima et al., 2011; Moser & Barrett, 2003, 2006). This has resulted in low and discontinued use of improved technology in Uganda. We used panel data to assess the pattern of adoption and disadoption.

Chapter 3 and 4 confirm that education is key in making initial adoption decisions, in accordance with studies by Kasirye (2013) and Moser and Barrett (2003). However, education does not affect the disadoption decision. Farmers with higher education can understand and appreciate the benefits of improved maize varieties which is important for the adoption decision. Institutional support, capacity building and supporting environments, e.g. adequate and efficient training programmes, are necessary for adoption take-off. These programmes should focus attention on including the vulnerable and illiterate farmers so that they are not left out.

Resource endowment, e.g. land and assets, were consistently important as the determinants of adoption and disadoption (chapter 3). With limited credit facilities due to underdeveloped financial markets, households may need to rely on their own savings to buy seeds. Poor households may not have savings at the beginning of a season. Provision of working credit facilities and buying seeds after harvest will enable farmers to participate in first time adoption and continued adoption. At a more advanced level, credit can help farmers engage in commercial farming. Credit may help the farmers with their needs considering the long period between planting and harvest of crops and mitigate crop failures which may result due to weather variability. Labour requirements of improved varieties, e.g. row planting, may require the use of hired labour and act as a constraint to adoption. Studies also found out that availability of labour contributed to differences in adoption (Feder et al., 1985) and the decision to continue or discontinue using a technology (Moser & Barrett, 2006). Additionally, availability of off-farm employment affects the availability of family labour, constraining the adoption of improved seeds (Mathenge et al., 2014; Tura et al., 2010).

The results of Chapter 2 and 3 concur with findings by (Bold et al., 2017); there is presence of adulterated/counterfeit seeds on the market. Some farmers experienced poor performance of bought improved seeds; the counterfeit seeds had low germination rate and low yields. This discouraged investment by farmers and they incurred losses due to poor germination and low yields. The uncertainty brought about by counterfeit seeds may lead to low adoption and disadoption decision. Michelson et al. (2021) argues that farmers' beliefs may be inconsistent with the reality in the market. However, Ashour et al. (2017) confirmed that farmers' beliefs about the quality of agricultural inputs are consistent with the reality in Uganda. Designing policies to ensure good quality seed will discourage the infiltration of counterfeit seeds into the seed market and avoid the 'lemon' problem.

Adoption and disadoption of improved maize varieties differed across the selected districts in the study area (Chapter 3). The importance and marketability of a crop or crop variety in a region contribute to the level of production and, consequently, the use of improved varieties. Limited uptake of bean variety in some areas was caused by non-preference of the promoted bean variety by farmers and buyers (chapter 2). Past studies found that differences in agro-ecological conditions and farmers' preference of the crop contribute to the adoption differences (Amare & Shiferaw, 2017; Asfaw et al., 2012; Shiferaw et al., 2014). The role of the crop/variety in the household, market linkage, and agro-ecological conditions (Almekinders et al., 2019) as well as financial benefits and household's food security and welfare (Kilwinger et al., 2020) influence seed access and demand.

Distance to input suppliers and markets influences transaction costs (Feder et al., 1985). Reduction in transaction costs to acquire modern technologies and market the output can increase the income. The statistical and qualitative results present conflicting evidence about the role of transaction costs in adoption decisions. Statistical results in chapters 3 and 4 show that distances to the nearest agro-dealer and market were not key in the decision to adopt or disadopt improved maize varieties. In contrast, qualitative results in chapter 2 show that long distances to the seed source hindered the accessibility and adoption of improved seeds. This means that the results depend on measurements and data collection methods. In qualitative data collection, individual farmers may have different perceptions when describing the long distances. For example, four kilometres could be near or far depending on the individual farmer. As at least the perception of distance matters, the seed companies and other agencies involved in distributing the improved seeds and other inputs should work with agro-dealer shops closest to the farmers to stock the inputs and thereby reduce the distance, consequently reducing the transaction costs. Infrastructure development will enable the farmers to bring their output to the market where the prices are high, thereby increasing profits.

Farmers are advised to adopt improved technologies due to their positive effect on productivity and incomes as confirmed by past studies such as (Khonje et al., 2015; Manda et al., 2018; Mason & Smale, 2013; Mathenge et al., 2014; Smale & Mason, 2014). Productivity is linked to marketable surplus and income, with increased income indicating an improvement in a household's livelihood. Chapter 4 confirms that improved maize varieties and improved management practices raise maize productivity. Surprisingly, maize income per hectare was not significantly different for adopters which is contrary the positive effect on total crop income. Although not studied, this could contribute to the disadoption decision by individual farmers. Higher costs of adoption of improved varieties may have contributed to reducing benefits in terms of maize income per hectare. There have been concerns whether adoption of improved maize varieties can improve a household's income on a sustainable basis, especially for the vulnerable poor farmers, due to differences in adoption (Ghimire & Huang, 2015). Wealthier farmers can afford the inputs leading to continuous adoption. In response, subsidies have been used by development agencies and governments to reach the vulnerable and poor farmers.

Subsidies have been used to raise levels of technology use and agricultural productivity (Mason et al., 2013; Mason et al., 2017). Subsidies may help in the adoption process by reducing the cost of acquiring inputs but when the programme ends the farmers, especially the poorest farmers, may discontinue using the technology. Additionally, subsidies may not be sustainable in the long run and only selected farmers have access. For example, in Zambia, wealthier farmers have more access to the subsidies (Mason & Smale, 2013). Long-term measures should be put in place to encourage and support not only adoption but also continued adoption for vulnerable groups.

Results in chapter 3 indicate that grain prices fluctuate during harvest time and were similar for improved and local varieties. Gilbert et al. (2017) also found out that output prices are unstable and volatile in Africa due to production/harvest shocks and seasonality, with maize having the highest seasonal price gap among the cereals. The decision to adopt improved maize varieties is risky due to high cost of seed and grain price volatility. Access to post-harvest storage facilities will help farmers store their products so that they obtain stable and fair prices when sold later. Maize grain prices play a key role in technology adoption and disadoption (Kijima et al., 2011). Lack of adequate measures to stabilise agricultural output prices is a key challenge in Uganda and it may affect the decision to grow improved maize varieties.

6.3.3 Livelihoods and income relationships

Livelihood diversification has been recognised as being important to rural households in developing countries. The proportion of off-farm income in the household income is growing (Davis et al., 2009). However, the results in chapter 5 indicate that agriculture is still the most important activity in rural Uganda. Irz et al. (2001) argue that agriculture is an important determinant of the growth of the non-farm sector in Sub-Saharan Africa. Exit from agriculture by most rural households is not likely to happen soon, so investment in the sector remains important. As increased agricultural productivity is especially important for rural households in Uganda, policy strategies should not only be prioritised to encourage a shift to non-farm employment but also investment in the agricultural sector.

All households were involved in annual farming, as shown in chapter 5. There is a trend emerging where farmers are allocating more land to annual crops such as beans, cassava and sweet potatoes (Mubiru et al., 2018). Heavy reliance on rain-fed agriculture and low use of inputs such as certified seed among smallholder farmers in Uganda result in low productivity and income (Chapters 3 and 4). Early maturing and drought-resistant crops/varieties help in reducing the risk of crop loss due to weather variability. Improvement of agricultural outcomes has a positive impact on economic development but depending on agriculture alone may delay development.

Non-farm employment is also important in the study region given that livelihood strategies including non-farm activities are more remunerative strategy than agriculture focussed strategies (annual and perennial cropping), as shown in chapter 5. Creation of non-farm employment such as self-employment and wage employment is possible through the connection between agriculture and other sectors, e.g. food processing (Pingali et al., 2019). Connecting agriculture with non-farm employment through production linkages, consumption linkages and input markets could help create non-farm employment. In particular, non-farm employment could be created through connecting different sectors such as agricultural value chains, e.g. input supply, output aggregation, storage, processing, and output marketing. When these sectors are functioning well, demand for agricultural produce will increase. This will require increased agricultural productivity, and therefore increased demand for improved technologies and management practices will result.

Individual households shifted from non-farm employment to farm employment and vice versa, indicating that participation in a strategy is temporary (chapter 5). Shifting from agricultural activities to non-farm activities may happen due to situations such as drought or small landholdings. In Ethiopia, low agricultural productivity drives households to engage in non-farm activities to maintain food security (Neglo et al., 2021), while low-quality non-farm employment may drive households to revert to agricultural activities. Non-farm employment needs to be of good quality to discourage movement from non-farm employment to farm employment (Chatterjee et al., 2016). Employment opportunities available around the year may help provide permanence in non-farm employment. On the other hand, commercialisation of agriculture could help households focus on agriculture and in turn on the development of non-farm employment opportunities.

Different factors influence households' choice of activities. In chapter 5, education is an important factor for engaging in off-farm activities. The importance of education for non-farm employment was documented in an earlier study by Schultz (Schultz, 1964). However, non-farm employment incorporates jobs requiring education e.g. salaried employment (teacher) as well as activities such as small businesses and farm labour, which do not require many skills or knowledge. Households in different locations face different opportunities to engage in non-farm employment and farm employment in terms of accessibility of these activities and the demand for products. Although not discussed in this thesis, proximity to urban areas is expected to encourage participation in non-farm activities.

Poor and vulnerable farmers may engage in the annual crop production strategy, which is the least remunerative strategy. Vulnerable farmers are locked out of the most remunerative livelihood strategies because they may not have access to skills and knowledge required for profitable non-farm employment (Chapter 5). Formal employment, e.g. salaried employment, is associated with decreased poverty, making households less vulnerable to poverty. Informal employment, e.g. casual employment, supports about 40 percent of the economic activity and employs 65 percent of the labour force in Uganda (Moyer et al., 2021). Informal employment is associated with vulnerability due to non-permanence of jobs, poor working conditions, and non-specified contracts where one can be laid off without notice. In salaried employment, such as teachers employed on a contract basis, may also be vulnerable to job loss due to non-renewal of contracts (chapter 5). This disrupts job sustainability and constant income sources. Integrating policy to support the informal sectors can raise efficiency and output moving Uganda to a sustainable economic growth.

6.4 Considerations for future research

The research in this thesis had various limitations. This section discusses limitations and considerations for future research.

First, we need to be cautious when drawing conclusions about the interactions of actors and the challenges faced during the implementation of demonstration plots using one case study. The biophysical conditions enable and constrain what can be learned. Different local people and organisations can lead to differences in learning processes and outcomes. Learning goes beyond the farmer and takes place in the interactions with and networks of broader stakeholders, which is not captured or analysed in this thesis. Future research which broadens the focus beyond on-farm individual learning to organisational, institutional and location aspects will help in effective coordination of the emerging problems during program implementation.

Second, our analysis is limited to three waves for chapters 3 and 4. It was difficult to estimate intertemporal patterns of adoptions due to a short panel and the difficulty of identifying early and late adopters using improved seeds. In chapter 4, we use two-way fixed effects with an IPW estimator to capture the effects of adoption. Establishment of causal effects on observed outcomes is problematic in impact assessment. In chapter 5, the panel data covering three years is relatively short to capture long-term livelihood strategy dynamics. Long-term surveys will help to capture the stable dynamics and outcomes.

Third, we use the classical definition of adoption as the binary decision to use a technology in combination with the extent of adoption. This definition has been criticised by scholars such as Glover et al. (2016) and Glover et al. (2019) because it does not capture the complex changes in sociotechnical aspects. We acknowledge that adoption is not a single event and may change over time due to reasons discussed in chapter 3. The study may not have exhausted the analysis of complex processes involved during the adoption and disadoption. In chapter 5, we may have not captured all the constraints and opportunities that shape the choice of livelihood strategy.

Fourth, existing evidence indicates that adoption of improved technologies increases income. On the contrary, chapter 4 shows that adoption of improved varieties does not increase the maize income per hectare. Even though the crop income increases in general, farmers may not benefit from growing maize alone using improved seeds. Further research is needed to learn the reasons for the positive relation between adoption of improved maize seeds and crop income but not maize income per hectare, considering that maize is the most grown crop in the studied area.

Finally, income was used as an outcome variable in chapters 4 and 5. Households may give inaccurate information, either overestimating or underestimating their income. It would be interesting to extend this research to more outcomes, e.g. a household's wellbeing, using asset ownership and consumption expenditure as indicators.

I will now discuss the opportunities for future research to further understand the issues in this thesis.

Chapter 2 shows that relationships and interactions among actors (farmers, demo-hosts, seed company staff and agro-dealers) play an important role in the knowledge and adoption diffusion process. Many actors -such as development agencies, scientists and researchers among others, are involved in designing, implementation and disseminating technologies. Further research on all the actors involved in the creation, diffusion and use of knowledge and those involved in coordinating and supporting these processes will help designing more effective programs in the future. The agricultural innovation system (AIS) approach is an aid for understanding the linkages, interactions, and relationships among different actors, and how they affect shared knowledge and the uptake of technology. The approach focuses on the whole process, starting from development, to diffusion, to adoption of new technologies (Odame et al., 2012; WorldBank, 2006). Broader analysis of each actor involved could help us to understand better the changes (or lack of change) induced by an intervention due to feedback collected at each level. Merging the AIS and adoption models can quantify the influence of each actor in adoption studies (Weyori et al., 2018).

The combination of the micro level and macro level helps to investigate low technology uptake and the challenges facing knowledge and technology transfer (Cunningham & O'Reilly, 2018). Macro-level analysis is abstract and involves bigger economic and social processes that influence individual behaviour. Macro-level analysis will help to evaluate the effectiveness of policy instruments designed to support effective technology transfer at regional or national levels. On the other hand, the micro level used in chapter 2 allows us to study individuals at a more personal level during face-to-face interactions. Further studies that take advantage of the complementarity and interactions of the two levels of analysis will give a full picture of the challenges and opportunities of adoption by adding more economic and sociological perspectives on how to design and implement intervention programmes. The use of micro variables and economic and social processes associated with them can increase technology adoption through policymaking.

In Chapter 3, fixed effects with inverse probability of treatment weights (IPW) was used to estimate the effect of improved maize varieties on productivity and income. The use of different approaches to estimate treatment effects, such as randomised controlled trials (RCTs) and instrumental variables, could help increase the robustness of results. RCTs evaluate the effectiveness of an intervention with minimal selection bias and influence of confounders because respondents are randomly assigned to an intervention. However, RCTs are not a panacea for all economic problems and impact evaluation studies (Barrett & Carter, 2010). Bulte et al. (2020) argues that the effect of an intervention may be overestimated; the effects may be due to other behavioural aspects such as the allocation of new seeds to the best plots. It is also costly to set up an RCT. Instrumental variable technique are used to estimate causal relationships when the intervention is not random. However, it was impossible to get a valid instrument for adoption status for our study Further analysis of cases where a valid instrument is available could complement the chapter 4 analysis and build confidence on the results.

Cluster analysis was used to identify the livelihood strategies in chapter 5. This analysis would have improved if there were more data on labour activities e.g. separate crop and livestock labour. Inclusion of ecological, social capital variables and natural capital (soil type) would be useful to define the constraints associated with a livelihood strategy choice. Participation in livelihood strategies differs in regions which may be driven by different constraints across the regions. Spatial analysis of the factors that drive diversification will give more insights in underlying constraints in participating in a certain livelihood strategy.

Chapter 5 confirms that agriculture is important among the smallholder households – all households were involved in annual crop production and some were involved in perennial crop production. In Sub-Saharan Africa, farm income contributes a large share of the household income. However, agriculture is prone to risks such as seasonality and fluctuations in output prices. Climatic and weather conditions should be taken into consideration when analysing livelihood strategies. In future research, it would be useful to collect more detailed qualitative data to establish the rural households' motivation behind their choices each year.

In this thesis, we used mixed methods that helped us to better understand the research problem as shown in individual chapters. However, we may not have captured all the complex processes. In chapter 5, we ma.ve not captured all the constraints and opportunities that shape the choice of livelihood strategy. A multi-disciplinary and interdisciplinary approach integrating more than two disciplines could help to overcome these deficiencies. According to Choi and Anita (2008), a multi-disciplinary approach is additive where different knowledge from several fields are brought together while remaining within their boundaries. An interdisciplinary approach is integrative and creates a coordinated and coherent picture by analysing, synthesizing and harmonising links between disciplines. Use of multi-disciplinary and interdisciplinary approaches in future would bring together different researchers to understand complex situations such as information dissemination, the learning process, adoption decisions and livelihood strategies.

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Summary

This thesis contributes to understanding of the learning mechanisms in information dissemination programs, agricultural technologies adoption process, effects of adoption of modern technologies and rural livelihood strategies and dynamics. The study is underpinned by detailed research using mixed methods to answer the research questions focusing on four districts; Tororo and Iganga in eastern region and Hoima and Masindi districts in mid-western region in Uganda. In separate chapters in the thesis, we investigate the factors that affect learning, adoption, and livelihood strategies and outcomes.

Chapter one provides the context of the thesis, general background of each chapter, highlights the main objective and research questions, underlying theory, and methodology used in the thesis.

Chapter two addresses the learning process and its effects of the adoption of improved maize and bean varieties in Uganda. More specifically, the concept of social, environmental and didactic learning was used to examine the use of demonstration plots to promote new varieties, role and interaction of actors (farmers, demo hosts, commercial actors and researchers) and the effect on the information dissemination and uptake of improved seeds. We find that the information dissemination, learning and uptake of improved seeds process were hindered constraints such as uncooperative demo hosts, poorly maintained demonstration plots, not considering farmers' needs and limited interactions among farmers, demo hosts and seed company officials. Social distance and established relationships are important in information dissemination process. Adoption of improved technologies was hindered by inaccessibility, unaffordability, and unavailability. This thesis shows that imbalance of social, environmental, and didactic learning hinders the learning process and adoption of improved technologies.

Chapter three looks at adoption dynamics, reasons for disadoption and crop management practices using in both improved and local maize varieties. Survey results show that the decision to adopt is not permanent; farmers shift from adoption to disadoption between years. Both adoption and disadoption were reversed in year 2 and 3. High cost and lack of funds to buy the inputs were reported as reasons for not using the improved seeds in all the years. Household heads with primary education and above, males and wealthier were more likely to adopt the improved maize varieties. Land and labour had

positive effect on the likelihood of adopting. Availability of family labour is required during peak seasons especially for adopters because improved management practices are required when planting improved varieties: row planting, number of weeding, harvesting.

Physical capital (oxen ownership and total assets) are positively influenced the size of land under improved seeds. Mechanical labour availability (oxen) and affordability of the seeds (wealthier farmers) is necessary for the extent of adoption. Gender of the household gender does not influence the extent of adoption as it does the decision to adopt, therefore accessibility is necessary for adoption. The proportion of land allocated to improved maize seeds is rarely affected by the coefficients except the land size. The proportion of land is positively affected by land size. Gender variable did not influence disadoption; the female headed households were more likely to disadopt compared to their male counterparts. Women may be constrained to purchase the improved variety seed, or they mainly focus on the local varieties mainly used for consumption since maize production as a cash crop is mainly male dominated. Most households did not allocate all the maize area to improved varieties.

Chapter four addresses the effects of the adoption of improved maize varieties on production and income in Uganda. As indicated above farmers recycle certified seed over a varied period of time. In this analysis we consider only certified seed bought in agro-dealer's shops as there could be underestimation if we considered the recycled seed as previously discussed. Adoption of improved varieties increased the yields and crop income. The increase in yields could as a result that farmers practice improved management practices because yields decreased over time due to weather variability. Although, the yields increased, this did not translate to increased maize income per hectare. There was no significant increase in maize income per hectare. Surprisingly, despite this result the crop income increased significantly among the adopters. Adopters may have allocated their best land and management practices and additional labour to other crops complementing the effect of certified seed. The higher crop income indicates that adopting farmers cultivate other crops for income.

Chapter five investigates the livelihood strategies and dynamics among the smallholder farmers in Uganda. We look at factors that influence the choice of a strategy, their outcomes, changes in livelihood

strategies and crop production between the strategies. All households engaged in annual farming. Our findings identified annual crops farming as the main strategy. Other strategies include self-employment, casual employment, salaried employment and perennial farming and involve more than one activity. The distribution of the livelihood strategies did not change much in the second year. Perennial/annual strategy cultivated the greatest number of crops and allocated more land to crop production in both years. Maize, beans, cassava, sweet potatoes, bananas were the most grown crops. However, the use of improved varieties in maize and bean production is low.

There were constraints associated with participation in other livelihood strategies compared to annual farming strategy. Age of the household head is positively correlated to the choice of livelihood strategies; self-employment/annuals, salaried employment/annuals and perennial/annual farming. Accumulation of resources may have contributed to the choice. Education is important in the choice of non-farm livelihood strategies. Higher literacy levels, knowledge and skills are required for non-farm employment. Dependency ratio influenced participation in perennial/annual farming and self-employment negatively and positively respectively. The households with less dependency ratio may be older and had an opportunity to plant the perennial crops. Obligations that increase with higher dependency ratio affecting participation in self-employment/annual strategy. Location of the households is important in determining the choice of livelihood strategies.

The outcomes (incomes) vary depending on the different strategies with non-farm strategies generating higher incomes. Salaried employment/annual was the most remunerative in 2013/14 while casual employment topped and salaried employment/annual came second topped in 2015/16. However, the difference was not much. Annual farming strategy was the least remunerative despite allocating most of their land and labour to the activity. Although, the distribution of livelihood strategies was relatively stable, individual households switched strategies. Farm strategies (annual and perennial/annual) were the most stable strategies although they were least remunerative. Shifting of households to a more remunerative non-farm strategy requires more resources, skills, and opportunity. Switching strategies may involve re-allocation of resources between the strategies or adopting/abandoning an activity.

In the synthesis, I highlight the significance of the main findings, how the studied themes are interrelated and contribution of the study to the literature of learning, agricultural technologies and livelihood strategies. These findings have an implication on how learning takes place and how these affects the technology adoption process. Most importantly, adoption dynamics will contribute to understanding more about adoption process which is not a one decision. Another major finding that emerged in this study is that despite agriculture being important for rural households in Uganda, it the least remunerative compared to other livelihood strategies.

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Completed Training and Supervision Plan

Claris Alice Karimi Riungu

Wageningen School of Social Sciences (WASS)

Completed Training and Supervision Plan

Name of the learning activity	Department/Institute	Year	ECTS*
A) Project related competences			
Advanced Econometrics, AEP 60306	WUR	2015	6
Research Design and Research Methods, YRM 20806	YRM	2015	6
Writing Research Proposal	DEC/KTI, WUR	2015, 2016	6
B) General research related competences			
WASS Introduction course	WASS	2015	1
'Factors affecting adoption dynamics of improved maize and bean production'	8th African Evaluation Association (AfREA) Conference, Kampala, Uganda	2017	1
C) Career related competences/personal development			
Research methodology: From Topic to Proposal	WASS	2015	4
Information Literacy including Endnote Introduction	WUR Library	2015	0.6
Techniques for Writing and Presenting a Scientific Paper	WGS	2016	1.2
The Essentials of Scientific Writing & Presenting	Wageningen in'to Languages	2016	1.2
Summer School Experiments in Developing Countries	Groningen University	2016	2
Multidisciplinary perspectives on quality improvement in value chains.	WASS	2016	1
Data processing and management using Census and Survey Processing System (CSPro)	Indepth Research Services	2016	1.25
WGS PhD Workshop Carrousel 2018	WGS	2018	0.3
Research Data Management 1, 2, 3 courses	WUR Library	2018	0.45
Project and Time Management course	WGS	2018	1.5
Interpersonal Communication for PhD students	WGS	2018	0.6
Reviewing a Scientific Paper	WGS	2018	0.1
Total			**34.2**

*One credit according to ECTS is on average equivalent to 28 hours of study load

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