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# The Role of Tenure Security in Farmers' Decision-Making on Investment in Improved Seeds: Insights from Mental Models

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## Abstract

*This paper applies a mental model approach to study the role of tenure security in farmers' decision-making on agricultural investment in Uganda. We investigate the role that both perceived tenure security and formal land rights, measured by the possession of land certificates, play. Our focus is on investment in improved seeds, a widely applied strategy in agricultural development and climate change adaptation. The study design leverages the roll-out of a large land demarcation and registration project, which creates exogenous variation in farmers' tenure security. Results show that, in contrast to expectations derived from economic theory, tenure security plays only a minor role in farmers' decision-making process to invest in improved seeds. Out of 15 potential factors determining a farmer's investment decision, both perceived tenure security and possession of a land certificate are among the least chosen factors, regardless of whether or not households participated in the land registration project. A heterogeneity analysis reveals that female-headed households value formalized land rights more than male-headed households.*

*JEL-Codes: Q12, Q15*

*Keywords: Agricultural investment; decision-making; land titles; mental models; tenure security*

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# 1. Introduction

Secure access to land is of fundamental importance for farmers' livelihoods, particularly in low- and middle-income countries (LMICs), where large parts of the population work in the agricultural sector (Lowder et al., 2015). In these countries, land tenure systems that govern access to land are often highly complex, fragmented, and overlapping. This can cause large heterogeneity in farmers' land tenure security,[1] which is often assumed to influence how farmers invest in their land and adapt to climate change (for a review, see Higgins et al., 2018). To strengthen tenure security, many governments and development practitioners in LMICs promote land demarcation, i.e., the mapping of parcel boundaries, and land registration, i.e., the issuance of formal land titles. Key objectives of land registration projects are improving tenure security, reducing the risk of land conflicts, increasing the efficiency of land markets, improving access to credit, and, importantly, encouraging farmers to invest in their land (Besley, 1995).

Economic theory predicts positive effects of tenure security on (agricultural) development (Besley, 1995). Yet, several systematic reviews document that empirical evidence on this relationship is mixed (Fenske, 2011; Higgins et al., 2018; Holden & Ghebru, 2016; Tseng et al., 2021). While most observational studies find that secure land tenure stimulates agricultural investment (Chirwa, 2005; Paltasingh, 2018; Santos et al., 2014), the effects may depend on the tenure security measure employed (Asaaga et al., 2020). Some experimental studies report either small effects (Goldstein et al., 2018) or no effects at all (Huntington & Shenoy, 2021). A number of reasons may explain these contradictory results. First, it is challenging to operationalize the concept of tenure security in empirical research (Simbizi et al., 2014). Second, some existing studies face methodological challenges, since tenure security is considered endogenous to many potential outcomes. For instance, in a randomized controlled trial of a land demarcation project, Huntington and Shenoy (2021) show that experimental methods and observational analysis of the same data arrive at conflicting conclusions. Third, the time horizon may matter, as tenure security is particularly important for longer-term investment (Abdulai et al., 2011; Huntington & Shenoy, 2021).

There is need to better understand the role of tenure security in farmers' decision to invest in agriculture. This study applies a mental model approach to generate new insights into farmers' investment decision-making process. We investigate the role that both perceived tenure security and formal land rights, measured by the possession of land certificates, play in farmers' decision-making process. The focus of our study is on farmers' decision to invest in improved seeds, a widely applied strategy in agricultural

[1] Tenure security refers to the confidence of land users in their rights to the land and their protection from external challenges. It encompasses different forms, including perceived, *de facto*, and *de jure* tenure security (Van Gelder, 2010).

development and climate change adaptation. Improved seeds – be it high-yielding, drought- or flood-tolerant, pest-resistant, or early maturing varieties – are identified as an important determinant of agricultural productivity in Sub-Sahara Africa (Evenson & Gollin, 2003). Moreover, improved seeds can enhance farmers' resilience to weather shocks (Anantha et al., 2021; Asfaw et al., 2012).

A mental model represents an individual's thought process about a real-world phenomenon. It is based on an individual's culture, values, beliefs, and experiences (Jones et al., 2011; van den Broek, et al., 2021a). A key feature of mental models are the causal beliefs about the phenomenon or process in question (Khemlani et al., 2014). Mental models are often based on interpretative lenses, popular narratives, and schemas developed through prior experience; they are activated automatically (Crocker et al., 1984; Goldberg et al., 2020). Mental models have been used to describe processes of natural resource management, e.g., in the context of fisheries (van den Broek et al., 2023; van den Broek, et al., 2021b), forests (Kearney et al., 1999), crop agriculture (Hoffman et al., 2014), and rangelands (Abel et al., 1998).

Our study design exploits unexpected changes in the implementation of a land demarcation and registration project implemented by the German Agency for International Cooperation (GIZ) in Uganda, which creates exogenous (but not random) variation in farmers' tenure security. We elicited mental models of the decision-making process to invest in improved seeds from 225 smallholder farmers in one Eastern Uganda district. Data collection took place in two sub-counties that were both target counties of the project: In one sub-county, GIZ had already implemented the project at the time of data collection, while in the other sub-county, GIZ had refrained from implementing it because another organization had announced plans to implement a similar project, which, however, in the end did not materialize. GIZ's land demarcation and registration project in Uganda is part of a global program that so far has been implemented in eleven countries across three continents, reaching more than 155,000 smallholder farm households (Land Portal, 2023). We test whether participation in the land demarcation and registration project changes the role that tenure security plays in households' decision-making process to invest in improved seeds. In addition, our analysis tests whether tenure security plays the same role in the decision-making of male and female-headed households. This focus is motivated by prior research documenting that women in LMICs are often less tenure secure than men (e.g., Doss et al., 2015; Meinzen-Dick et al., 2019).

This study contributes to the literature in three ways: First, the mental model approach allows us to study the decision-making process of investing in improved seeds as opposed to the adoption itself, which most existing studies analyze with survey data. We study the decision-making process as perceived by farmers, a perspective that can complement other indicators on the effectiveness of development interventions (e.g. the number of participants adopting agricultural investments). More specifically, the mental model approach allows us to tackle the relative importance that respondents ascribe to tenure

security and land certificates in the investment decision-making process. This way, our study introduces a novel approach to development economics that produces more nuanced insights into the tenure security investment nexus. Second, by exploiting exogenous variation in tenure security induced by GIZ's land demarcation and registration project, our study avoids endogeneity issues that often hinder rigorous analyses of the link between tenure security and agricultural investment. Third, our study makes a methodological contribution to the mental model literature. Most existing studies, many in the field of psychology, elicit mental models from a small number of respondents, typically less than 20, and then analyze mental models visually. Our study elicits a large number of mental models in a standardized way, which allows for statistical comparison between groups.

Results show that tenure security plays only a minor role in farmers' decision-making process to invest in improved seeds. Out of 15 potential factors determining a farmer's investment decision, both perceived tenure security and possession of a formal land certificate are among the least chosen factors, regardless of whether or not households participated in the land registration project. A heterogeneity analysis reveals that female-headed households attribute a much stronger influence of land certificates on the use of improved seeds compared to male-headed households.

The paper is organized as follows. In section 2, we provide information on the land tenure context in Uganda and introduce the GIZ land demarcation and registration project. Section 3 outlines the study design, methods, and approach to elicit mental models. Section 4 presents results, which are discussed in section 5.

## 2. Land tenure in Uganda and the land demarcation and registration project

Like many African countries, Uganda has different land tenure types in place, some of which exist simultaneously and overlap. Land in Uganda can be held under customary tenure, freehold tenure, leasehold tenure, and Mailo tenure – a tenure type only known in Uganda and a relic of British colonial rule. Customary tenure is most widespread, covering about 75% of all land holdings in Uganda (MLHUD, 2013). Under the 1998 Land Act and the 2013 National Land Policy, owners of customary land can apply for certificates of customary ownership (CCOs). Expert interviews conducted by the authors (L.M. and J.A.) in Uganda in April 2022 revealed that uptake of CCOs has so far been slow, in part due to the high costs of surveying land, lack of information about land certification, and lack of government capacities to speed up registration programs.

Since 2016, GIZ has been implementing the Responsible Land Policy in Uganda (RELAPU) project. It is implemented in Central Uganda (Mubende, Kassanda, and Mityana districts), North-Western Uganda (Arua district), Eastern Uganda (Katakwi and Soroti districts), and Northern Uganda (Amolatar and Dokolo districts). The RELAPU project primarily targets smallholder farmers and aims at "formalizing

land rights for 80,000 households by demarcation of land parcels, their digital documentation, and eventually the issuance of land certificates" (GIZ, 2019, p. 9). The approach followed in the RELAPU project was designed by GIZ in partnership with the Government of Uganda, civil society organizations, and Makerere University (Musinguzi et al., 2021). The overall RELAPU project budget amounts to almost 19 million Euro (GIZ, 2022).

The RELAPU project implements land demarcation and registration in two steps, with strong involvement of governmental and traditional authorities throughout the process. In the first step, parcel boundaries are mapped by a village team in participating villages, with both landowners and neighbors present during the mapping exercise. A village parcel map is then produced for the whole village, which is reviewed and, if needed, edited by the community. Landowners receive a land inventory protocol (LIP) of their mapped land. If either parcel boundaries or the ownership of a parcel is contested, no document is produced and the conflict first needs to be resolved either with support of the RELAPU project team, or, in more severe cases, in court. In the second step, households who wish to obtain a CCO are supported by the RELAPU project team with the application process, both administratively and financially. For instance, in Eastern Uganda, households pay on average 200,000 Uganda Shillings (UGS) (approximately 55 USD) when applying for a CCO autonomously. With support from the RELAPU project households only pay about 15,000 UGS (approximately 4 USD) to obtain a CCO.

Our study focuses on the implementation of the RELAPU project in Soroti district, which is located in Eastern Uganda. In Soroti district, implementation of the RELAPU project started in March 2016 and was completed in October 2021, about half a year before we collected data.

In 2014, Soroti district had a population of almost 300,000 inhabitants. For about 70% of the population, crop farming is the main income source (UBOS, 2017). Soroti is located in one of the poorest regions of Uganda. It was severely affected by the civil war and is frequently struck by dry spells and floods, which are particularly harmful due to the flat terrain. Land plays an important role in post-war recovery and is households' central asset in this agrarian-dominated region. Most land in Soroti is under customary tenure and, before the start of the RELAPU project, only a few households were in possession of a CCO. Conflicts on parcel boundaries and other types of land conflicts are common, which sometimes turn violent. A survey conducted in Soroti district in 2016, before GIZ started implementing the RELAPU project mapping activities, indicates that about 50% of households had experienced land disputes (GIZ, 2017). The governmental capacity for land administration and registration in Soroti district was low, with less than 5% of parcel boundaries mapped (ibid.).

# 3. Methods

## *3.1 Study design and sample*

We chose Soroti district as our study area to exploit exogenous variation in tenure security induced by the RELAPU project. GIZ applied a range of criteria to select suitable sub-counties for the RELAPU project within Soroti district; criteria include strong capacity of local authorities, low share of mapped land, high prevalence of land conflicts, frequent occurrence of drought, and accessibility (GIZ, 2017). As a result of this exercise, three of the eight sub-counties of Soroti district were earmarked as target sub-counties of the RELAPU project, including Katine and Gweri sub-counties. However, GIZ eventually refrained from implementing the RELAPU project in Gweri sub-county, as another development organization announced its intention to implement a similar land formalization project, which ultimately did not materialize. We exploit this *ad hoc* change in project implementation and compare households in Katine sub-county, where the RELAPU project was implemented (treatment group) with households in Gweri sub-county, where a similar project was unexpectedly not implemented (control group).[2] We hypothesize that for households participating in the RELAPU project, tenure security plays a more prominent role in the decision-making process on the investment of improved seeds compared to households in the control group.

The usage of improved seeds is a commonly discussed strategy in rural Uganda. About 35% of respondents used at least one type of improved seeds at the time of data collection (Table A1 in the Appendix). Both government extension agents and NGOs commonly promote the adoption of improved seeds. Qualitative observations during fieldwork revealed that it can be reasonably assumed that farm households in the local context have good knowledge about different types and the benefits of improved seeds.

Fig. 1 shows the location of Soroti district in Uganda and the sub-counties within Soroti. Table 1 displays characteristics of Katine and Gweri sub-counties before the RELAPU project started. Both sub-counties are similar in terms of population density, household size, the share of households engaged in subsistence-oriented farming, and the share of households receiving remittances. In both sub-counties, less than 1% of land had been mapped as of 2001.

We collected data in seven and ten villages in Katine and Gweri sub-county, respectively.[3] Within each village, households were purposefully selected to participate in the study. Village chairpersons were

[2] Since entire villages were enrolled in the RELAPU project, we consider spill-over effects across villages likely. To address this concern, we define treatment and control groups at the sub-county level.

[3] All data collection was done by L.M. and J.A.

asked to nominate both male- and female-headed households and, in the case of Katine, a sufficiently large number of households who had already obtained a land certificate (i.e., a CCO). From all respondents, two types of data were collected: (i) mental models (described in section 3.2) and (ii) socio-economic survey data (from here on "AGRICA survey") that recorded key socio-demographic, agricultural, and land-related information. Since land is a highly sensitive topic in Uganda, inquiries about land ownership, land certificates, and tenure security may raise suspicion and fear among survey respondents. Great care was taken to explain the research purpose, respondents' rights, and data protection provisions to respondents. We then asked for respondents' informed consent to participate in our study. This was done either verbally, if respondents had limited literacy, or in writing, using consent sheets devised for this study.

Although the RELAPU project was implemented in almost all villages in Katine sub-county, 28 of the 125 households initially sampled in Katine reported they did not participate in the RELAPU project. Households gave three main reasons for this: First, outstanding land conflicts (often boundary disputes), which, according to requirements of the RELAPU project, first have to be settled, sometimes in court, prevented the land demarcation; second, proximity to wetlands, which required the presence of an environmental official from the district to confirm the land demarcation; and third, incomplete RELAPU project outreach, which in part was due to difficulties in project implementation faced by GIZ's local implementing partner. We verified the information on project participation as self-reported by sample households with official LIPs issued by GIZ and found only two cases in which the information provided by the households diverged from the GIZ documentation. We excluded households in Katine sub-county who did not participate in the RELAPU project from the analysis, which resulted in a sample size of N=97 treatment households in Katine sub-county and N=128 control households in Gweri sub-county.

For a valid comparison, treatment and control households should be similar along key socio-demographic characteristics, except for their participation in the RELAPU project. Table A1 in the Appendix provides descriptive statistics of key variables of interest for both groups, derived from the AGRICA survey. Unconditional t-tests on the equality of means show that the two groups are not statistically different in terms of climate adaptation strategies practiced at the time of the survey, income sources, and most characteristics of the household head. However, we did find significant differences between treatment and control households in terms of livestock ownership, farm size, the extent of subsistence orientation, household size, and ethnicity. These differences mostly stem from the two sub-counties' distinct ethnic composition, which, however, has no direct link with land tenure characteristics. As a likely result of the RELAPU project, we found significant differences in key land tenure characteristics: about 35% of treatment households are in possession of a land certificate (CCO), compared to 5% of households in the control group. Similarly, a significantly lower share of households

in the treatment group (9%) reported being currently involved in a land conflict, compared to 22% of households in the control group.

**Fig. 1: Map showing the location of Katine and Gweri sub-counties in Soroti district.**


**Table 1: Characteristics of Katine and Gweri sub-counties before the start of the RELAPU project.**

| Characteristic | Katine sub-county (treatment) | Gweri sub-county (control) | Source |
|---|---|---|---|
| Percentage of land mapped in 2001 | 0.003 | 0.007 | GIZ (2017) |
| Population density in 2014 (square km) | 156 | 158 | UBOS (2017) |
| Household size in 2014 | 6.0 | 5.9 | GIZ (2017) |
| Percentage of households engaged in subsistence farming in 2014 | 0.9 | 0.896 | UBOS (2017) |
| Percentage of households receiving remittances in 2014 | 0.229 | 0.23 | UBOS (2017) |

### *3.2 Mental model elicitation: The M-Tool*

The concept of mental models has its origins in psychology (Craik, 1967; Johnson-Laird, 1983), but is also widely used in other research fields, including education, natural resource management, organizational studies, and system dynamics (Jones et al., 2011). Many methods exist for eliciting mental models, including semi-structured interviews (ibid.) and graphic methods in which respondents visualize their mental model, such as fuzzy cognitive mapping (Hamilton et al., 2019; Özesmi & Özesmi, 2004).

We use the M-Tool, created by van den Broek et al. (2021a), which was developed to facilitate the systematic elicitation of mental models among low-literacy populations and validated with a sample of Tanzanian fishers (van den Broek et al., 2021b). This feature makes it particularly suitable for our case study since almost 30% of the adult population in the Soroti district has limited literacy (UBOS, 2017). Another advantage of the M-Tool is that instructions are pre-recorded and, thus, standardized in the tool, which minimizes the impact of elicitation style across research assistants, although some respondents needed repeated encouragement to become acquainted with the tool. With the M-Tool approach, respondents create visual influence diagrams that show their causal beliefs with regard to a specific question, in our case, what factors influence the decision to invest in improved seeds. As a preparatory step, a fixed set of drivers – factors deemed influential in the decision-making process – was developed by the authors (described in more detail below).[4] In the actual mental model elicitation, respondents then selected from these drivers to create their mental model. The fixed set of drivers limits the tool's flexibility and may lead to framing effects, where respondents are influenced by the choice of drivers presented to them. However, this risk is partly mitigated as only drivers perceived as relevant by respondents are included. Due to the standardized elicitation process, the mental models can be analyzed quantitatively. This is not possible with alternative approaches, where mental models are elicited without a pre-defined set of drivers and respondents are likely to use different terms for similar concepts. Our quantitative approach of eliciting mental models also facilitates heterogeneity analyses, since mental models from different groups can be compared.

We applied an iterative process to develop a fixed set of drivers influencing farmers' decision-making on investing in improved seeds to include in the M-tool. First, we surveyed the literature and identified 19 relevant drivers. Second, we conducted a pilot survey with 20 respondents in Soroti district in March 2022 to validate the set of drivers. Three drivers on the initial list were considered not important by participants and four new concepts were added by respondents, which resulted in a list of 20 drivers. In a third step, the 20 drivers were presented at a stakeholder workshop attended by development

[4] In the mental model literature, the term node is sometimes used when referring to drivers.

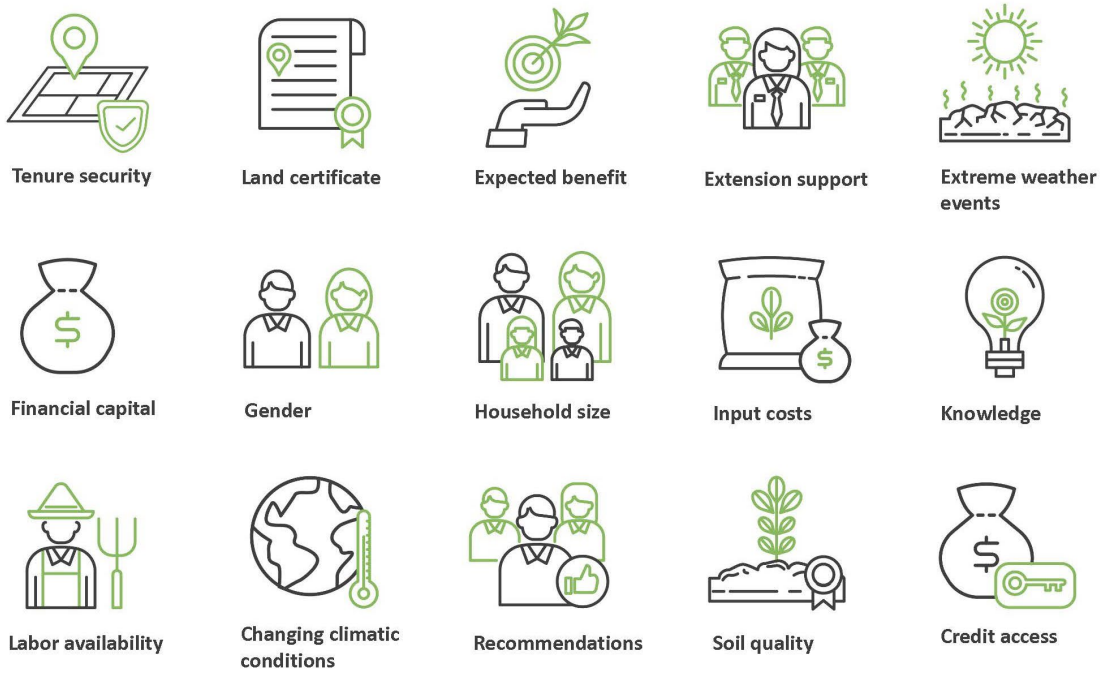
practitioners, government representatives, and researchers that we organized in Kampala in April 2022. Stakeholders were asked to take the perspective of a Ugandan farmer and draw a mental model with the M-Tool. After analyzing data from the pilot mental models elicited from stakeholders, we reduced the number of drivers to the 15 most frequently included drivers in order to keep the task manageable for respondents, while still allowing for nuanced mental models.

Figure 2 displays icons for the 15 drivers included in the final M-Tool set-up. The main drivers of interest in this study are *tenure security* and *land certificate*. *Land certificate* refers to Customary Certificates of Ownership, the formal land titles households in Uganda can obtain for land held under customary tenure. *Tenure security* captures the feeling of households that they are safe on their land and do not need to fear losing their land. This may or may not coincide with or be determined by possessing a land certificate. Descriptions of the other drivers as presented to the participants in the mental model task are shown in Table A2 in the Appendix.

In M-Tool, respondents were asked to map their decision-making process of investing in improved seeds. Respondents first selected drivers they considered relevant. They could then choose arrows with different thicknesses that indicated the strength of influence of a given driver (thin for moderate influence, medium thickness for medium influence, and thick for strong influence). Respondents also indicated whether a driver had a positive influence (blue arrow) or a negative influence (red arrow). Besides direct connections of a given driver and *improved seed use*, indirect connections between drivers could be drawn to indicate intermediate relationships. Figure 3 displays the M-Tool app: Panel A displays the initial mapping screen. The outcome, *improved seed use*, was placed on the right side of the M-Tool screen. Respondents chose from the drivers represented by icons on the left side of the screen. Panel B shows the example of a mental model drawn by one respondent. All instructions were included as audio files in the dominant local language, Ateso.

Eliciting a mental model from one respondent took on average 60 minutes. This included an introduction of the aims of the research, obtaining informed consent, an introductory video in the app, a short practice exercise to verify that the respondent understood what to do, the presentation of the drivers available to choose from, the completion of the mental model, and completion of the AGRICA survey on respondents' socio-economic characteristics. For each mental model, an edge list, i.e., a list of all connections, was recorded that contains information on the connections between drivers and the outcome and the strength of each connection. This edge list was merged with the socio-economic data from the AGRICA survey and analyzed in R.

**Fig. 2: Set of potential drivers of improved seed use included in the M-Tool set-up.**

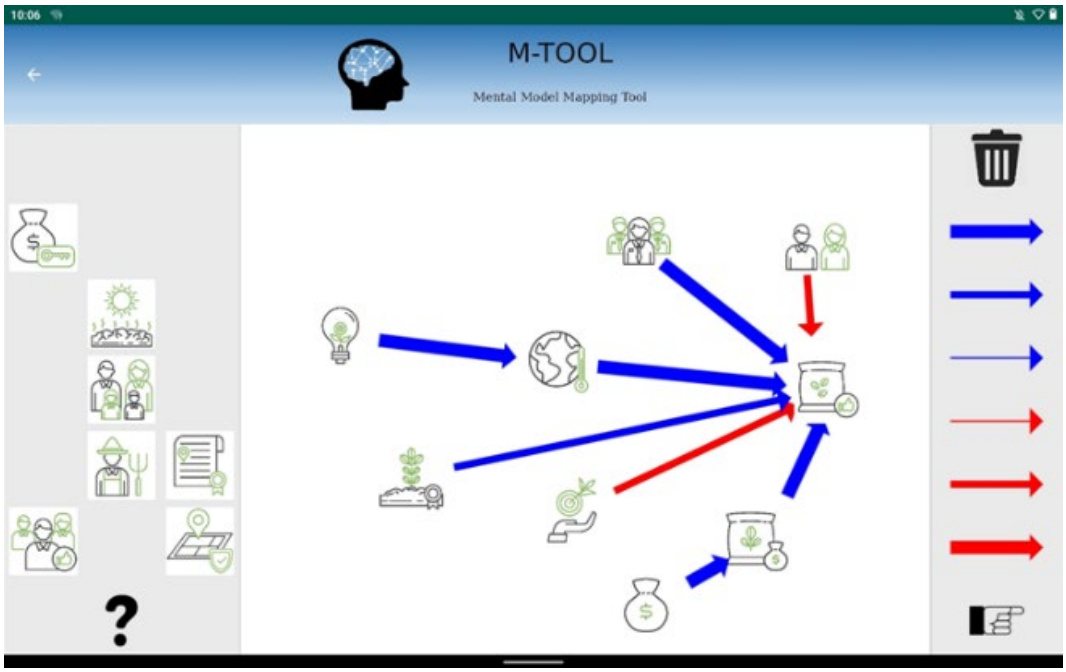



Source: The authors.

**Fig. 3: M-Tool app screen.**

*(a) Initial mapping screen*


*(b) Example of mental model drawn by one respondent*




Source: The authors.

### *3.3 Data analysis*

We first compare mental models across respondents in the treatment and control groups, applying t-tests on differences in means. Next, we explore a source of potential heterogeneity, the gender of the household head.

Our analysis focuses on three levels: (1) the driver *tenure security,* (2) the driver *land certificate*, and (3) mental models as a whole. For both drivers, we seek to understand their (relative) importance in farmers' mental models. We draw on techniques from network analysis to compute several centrality measures. Table 2 provides an overview of measures of interest.

For the first analysis level, we start by computing the frequency with which the driver *tenure security* is included in farmers' mental models, i.e., the share of respondents who included it. Next, we compute the rank of the *tenure security* driver relative to the other 14 drivers, thus measuring its relative importance. The rank is derived from the frequency of inclusion of the *tenure security* driver in all mental models. The last measure is the mean out-strength of all outgoing arrows from the *tenure security* driver to either the outcome *use of improved seeds* or any other driver in the mental model. To compute the mean out-strength, we draw on the strength and sign respondents assign to a given connection (i.e., arrows in Fig. 3b). The out-strength measure ranges between -3 (indicating a strong and negative influence) to +3 (indicating a strong and positive influence). By definition, the mean out-strength is only calculated for the sub-sample of respondents who included the *tenure security* driver in their mental model in the first place.

For the second analysis level, we compute the same three measures – frequency, rank, and mean out-strength – for the driver *land certificate*.

The third analysis level, considering mental models as a whole, characterizes the decision-making process in more general terms. The measure of interest is the mean strength of direct connections toward the outcome *use of improved seeds*, which captures in how far respondents perceive the sum of drivers to hinder or facilitate investment in improved seeds.

**Table 2: Definition of measures of interest.**

| Analysis level | Name of measure | Description |
|---|---|---|
| *Tenure security* driver | Frequency | The number of respondents who included the driver *tenure security* in their mental model, divided by the total number of respondents. |
| | Rank | The position of the driver *tenure security* in the ranked list of 15 available drivers, based on the frequency of inclusion. |
| | Mean out-strength | The mean strength of all outgoing arrows from the driver *tenure security.* |
| *Land certificate* driver | Frequency | The number of respondents who included the driver *land certificate* in their mental model, divided by the total number of respondents. |
| | Rank | The position of the driver *land certificate* in the ranked list of 15 available drivers, based on the frequency of inclusion. |
| | Mean out-strength | The mean strength of all outgoing arrows from the driver *land certificate.* |
| Whole mental model | Mean strength of direct connections to *improved seed use* | The mean strength of all incoming arrows to the driver *improved seed use* in a mental model. |

Source: The authors.

# 4. Results

## *4.1 The role of tenure security in decision-making*

Aggregated visual representations of farmers' mental models on the decision to invest in improved seeds are displayed in Fig. 4. Panel A shows aggregated results for treatment households (N=97) living in Katine sub-county who participated in the RELAPU land demarcation and registration project, while panel B shows aggregated mental models of control households (N=128) in Gweri sub-county, where the RELAPU project was not implemented. In both groups, the majority of connections are positive in sum. Respondents most often drew direct connections from each driver to the outcome *improved seed use*, while some indirect connections, encompassing connections between two or more drivers, were also drawn. On average, respondents in the treatment and control group included 9.08 and 9.62 drivers in their mental model, respectively, out of 15 possible drivers in total. For our research question, the main drivers of interest are *tenure security*, measuring whether a household feels certain about its land rights, and *land certificate*, indicating whether a household has obtained formal land rights.

To explore the role of tenure security in farmers' decision-making process to invest in improved seeds, we compare the mental models of treatment and control households with statistical methods. Table 3 displays mean values of centrality measures characterizing mental models of treatment and control households as well as p-values from unconditional t-tests on the equality of means. When considering the role of the driver *tenure security* in farmers' mental models, we do not detect statistically significant differences across households that stem from participation in the land demarcation and registration project. A similar share of treatment and control households (33% and 30%, respectively) included the *tenure security* driver in their mental model. The difference in means is not statistically significant, with p=0.69. For both groups of households, the driver *tenure security* is among the least important, ranked 12$^{th}$ out of 15 drivers among treatment households and ranked 14$^{th}$ among control households. Other drivers, such as financial capital, input costs, and the expected benefit of improved seeds, were included more prominently in the mental models of both groups (Table A3 in the Appendix). Similarly, among the sub-sample of households that included the *tenure security* driver in their model, there is no significant difference between treatment and control households in the mean out-strength assigned to the *tenure security* driver (Table 3, p=0.44).

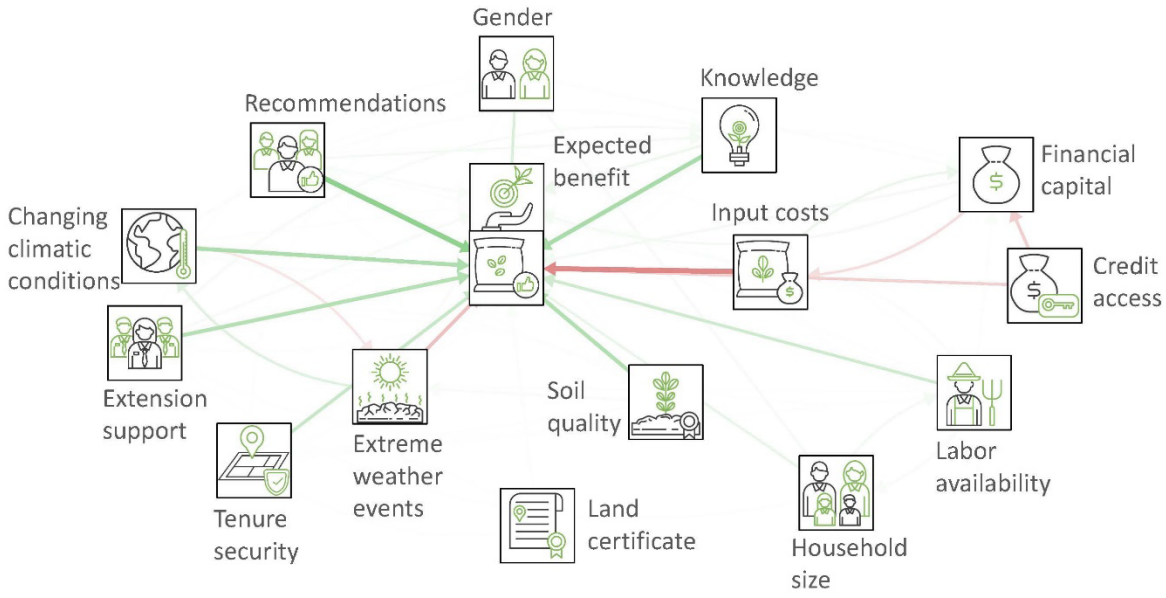
The picture looks roughly similar for the driver *land certificate*. Here, a slightly larger share of treatment households (19%) included the *land certificate* driver in their mental model, compared to 12% of the control group. The difference is marginally significant, with p=0.15. However, for both groups, *land certificate* is the least important driver, ranking 15$^{th}$ out of 15 drivers. Treatment and control households do not differ in the mean out-strength of the driver *land certificate* (p=0.94).

One potential explanation for the minor role of tenure security in farmers' decision-making process may be the fact that only a sub-sample of treatment households had acquired a land certificate by the time of data collection. When restricting the sample to treatment households that are in possession of a land certificate (N=34), we obtain similar results (Table A4 in the Appendix): There is no difference across treatment and control households in the frequency with which the drivers *tenure security* and *land certificate* are included in farmers' mental models, nor in the mean out-strength of the drivers. Hence, we do not find support for the hypothesis that it is formal land rights that determine the role of tenure security in households' mental models of investing in improved seeds.

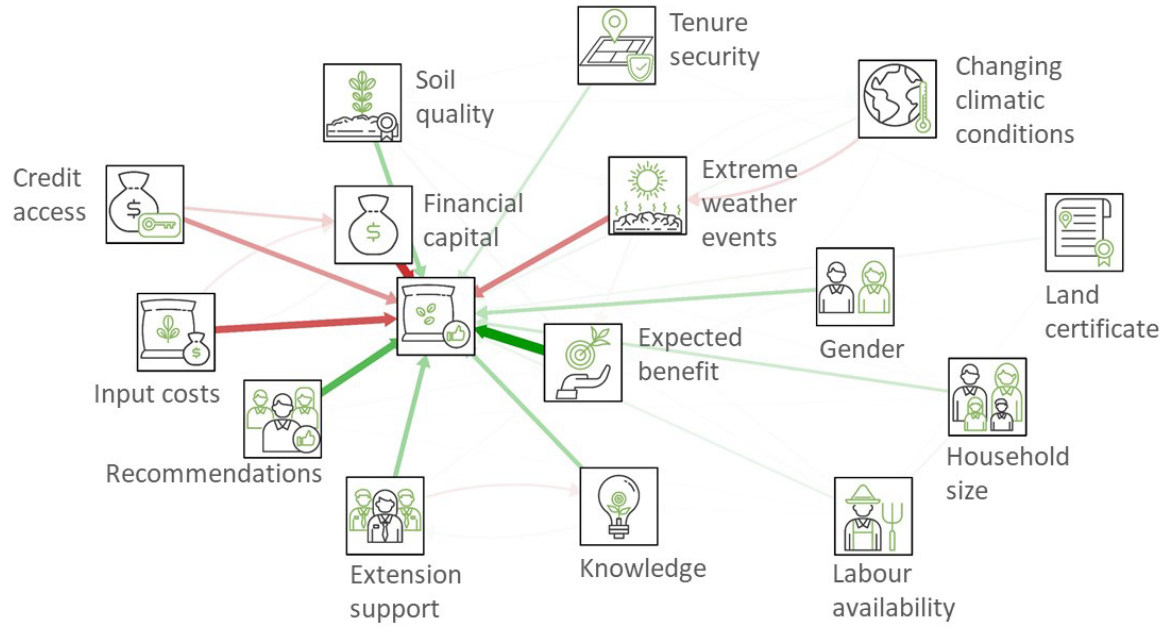
The only clearly detectable effect of participating in the land demarcation and registration project is on the mental model overall. When considering the mean strength of all direct connections to the driver *improved seed use* in farmers' mental model, the mean strength is 0.46 among treatment households and 0.20 among control households. The difference in mean strength between the groups is statistically significant at the 10% level, with p=0.07. This suggests that, on average, households in the treatment group identified factors that are more strongly and more positively related with the decision of investing in improved seeds than control households.

**Fig. 4: Aggregated mental models for treatment and control households.**

*(a) Treatment households*




*(b) Control households*




Note: The connections (arrows) are added up across respondents, which leads to some overall positive (green) and some overall negative (red) connections. The thickness of arrows indicates the mean strength assigned to a given connection. The strengths are standardized to account for the different sample sizes across treatment and control groups. The distance between the drivers reflects the absolute strength of the connection between them. The exact position of drivers is also determined by other factors, e.g., to avoid overlapping of drivers. Data source: AGRICA mental models exercise.

**Table 3: Comparison of mental models across treatment and control households.**

| Measure | Treatment households (N=97) | Control households (N=128) | Df | T-stat | P-value |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Tenure security driver | | | | | |
| Frequency | 0.33 | 0.30 | 223 | -0.41 | 0.69 |
| Rank | 12 | 14 | | | |
| Mean out-strength | 1.22 | 0.87 | 69 | -0.78 | 0.44 |
| Land certificate driver | | | | | |
| Frequency | 0.19 | 0.12 | 223 | -1.44 | 0.15 |
| Rank | 15 | 15 | | | |
| Mean out-strength | 0.28 | 0.33 | 31 | 0.08 | 0.94 |
| Whole model | | | | | |
| Mean strength of direct connections to improved seeds | 0.46 | 0.20 | 223 | -1.80 | 0.07* |

Notes: Columns 4 and 5 report results from unconditional t-tests of the equality of means between treatment households (i.e., households participating in the RELAPU land demarcation and registration project) and control households (i.e., households not participating in the RELAPU project), with * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Data source: AGRICA mental models exercise and AGRICA survey.

### *4.2 Heterogeneity of effects by gender of household head*

The existing literature documents that tenure security in many empirical contexts differs by gender. We thus analyze potential heterogeneity of effects due to gender differences in household leadership.[5] Results, displayed in Table 4, show that the share of male- and female-headed household that included the driver *tenure security* in their mental model is not significantly different (p=0.28). Male-headed and female-headed households place the driver *tenure security* on a similar rank (12$^{th}$ and 11$^{th}$, respectively, out of 15). There is no significant difference in the mean out-strength that both groups assign to the driver *tenure security* (p=0.94). Note, however, that the sample sizes in both groups differ considerably.

For the driver *land certificate*, results are more nuanced. There is no significant difference in the frequency with which male-headed and female-headed households include the driver *land certificate* (14 and 19%, respectively, with p=0.34), which is low overall. Both groups of households place this driver on the very last rank among the 15 possible drivers. However, for those female-headed households who included the driver land certificate in their mental model, it is of greater importance compared to male-headed households. The mean out-strength of the *land certificate* driver accorded by female-headed households is 1.33 compared to -0.08 for male-headed households; this difference is statistically significant at the 10% level (p=0.07). This indicates that female-headed households perceive the role of land certificates in the decision-making process to invest in improved seeds much more positively compared to men, who even accord a negative influence. Interestingly, this finding is not driven by differences in formal land rights across male-headed and female-headed households: The two groups do not differ significantly in terms of the share of households in possession of a land certificate (p=0.87), the average perceived tenure security (p=0.87), or the share of households currently experiencing a land conflict (p=0.84) (Table A6 in the Appendix).

The gender difference in influence assigned to the mean out-strength of the *land certificate* driver is especially remarkable given the fact that male-headed household heads draw, on average, much more "positive" mental models, i.e., they identify more factors with positive influence in the decision-making process.[6] The mean strength of all direct connections to *use of improved seeds* assigned by male-headed households is 0.40 versus -0.05 for female-headed households (p=0.01).

[5] Note that the sample size is too small to consider the interaction between participation in the RELAPU project and gender of household head. Of the male-headed and female-headed households in our sample, a similar share, 41% and 49% respectively, participated in the RELAPU project (Table A6 in the Appendix).

[6] For instance, male-headed households accord a much more positive influence to the factors *extension*, *knowledge*, and *labor* than female-headed households (Table A5 in the Appendix).

**Table 4: Comparison of mental models across male- and female-headed households.**

| Measure | Male-headed household (N=177) | Female-headed household (N=47) | Df | T-stat | P-value |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Tenure security driver | | | | | |
| Frequency | 0.30 | 0.38 | 222 | 1.09 | 0.28 |
| Rank | 12 | 11 | | | |
| Mean out-strength | 1.02 | 1.06 | 69 | 0.07 | 0.94 |
| Land certificate driver | | | | | |
| Frequency | 0.14 | 0.19 | 222 | 0.96 | 0.34 |
| Rank | 15 | 15 | | | |
| Mean out-strength | -0.08 | 1.33 | 31 | 1.88 | 0.07* |
| Whole model | | | | | |
| Mean strength of direct connections to improved seeds | 0.40 | -0.05 | 222 | -2.58 | 0.01** |

Notes: Columns 4 and 5 report results from unconditional t-tests of the equality of means between male- and female-headed households, with * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Data source: AGRICA mental models exercise and AGRICA survey.

# 5. Discussion

This study provides new insights into the role of tenure security in the decision-making process of farmers in one district of rural Uganda to invest in improved seeds. Mental models were elicited from 225 respondents to identify factors influencing individuals' decision-making process, using a standardized procedure. Our study design exploits changes in the implementation of a large-scale land demarcation and registration project by GIZ that supported households in resolving land disputes, mapping parcel boundaries, and obtaining customary land certificates, thereby creating exogenous variation in tenure security. Comparing the mental models of RELAPU project participants (living in one sub-county) and RELAPU non-participants (living in another sub-county), our statistical analysis explores the roles of both perceived tenure security and land certificates in farmers' decision-making. Two main findings emerge.

First, participating in the land demarcation and registration project does not affect the role of tenure security in farmer decisions to invest in improved seeds. For RELAPU project participants and non-participants, perceived tenure security played a similar role in the decision-making process. Similarly, project participants and non-participants do not differ in the role they attribute to possessing a land certificate in their mental models. Both project participants and non-participants consider perceived tenure security and formal land certificates much less important, on average, than other factors, such as financial capital, the expected benefit of improved seeds, and receiving extension advice. In particular, possession of a land certificate is the least chosen factor among both participants and non-participants.

Second, male-headed and female-headed households accord different importance to land certificates in their mental models. Male-headed households regard the influence of land certificates in their decision to invest in improved seeds to be of moderate strength and negative, with the possession of a land certificate reducing the likelihood of investing in improved seeds. In contrast, female-headed households attribute a strong and positive influence of land certificates in their decision-making process.

Overall, our findings on the minor role of tenure security in farmers' investment decisions contradict predictions of economic theory. They also contrast with many observational studies highlighting the importance of tenure security for farmers' investment decisions (e.g., Ali et al., 2014; Bambio & Agha, 2018; Bellemare et al., 2020; Besley, 1995; Higgins et al., 2018; Kemper et al. 2015; Lawry et al., 2017; Santos et al., 2014). Our results are in line with more recent experimental studies on tenure security, land formalization, and agricultural investment (Goldstein et al., 2018; Huntington & Shenoy, 2021), which also find small or no effects of tenure security on agricultural investment. Similar evidence, demonstrating the absence of substantial impacts from formal land tenure, has also surfaced in empirical research focused on various other outcomes, including rural economic development (Ho, 2021) and the cultivation of coca (Thomson et al., 2022).

Several features may explain the minor role of tenure security in our study. First, our focus is on investment in improved seeds, which, as a rather short-term investment, may not require tenure security, compared to more long-term investments, such as agroforestry (Abdulai et al., 2011; Deininger & Jin, 2006). Second, the relatively small number of households in both groups that includes land certificates and tenure security in their mental model makes it difficult to identify differences, as it effectively limits statistical power. Thus, we cannot interpret the null results obtained from comparing both groups as actual failure to reject the null hypothesis of no systematic difference between the treatment and control groups. Since mental models – to the best of our knowledge – have never been used to study the decision-making process to invest in improved seeds and the potential role of tenure security therein, we had little *a priori* information on reasonable effect sizes to expect. This is another finding of the study: Potential effects of tenure security or land certificates on improved seeds likely concern a smaller group of people than expected, requiring larger sample sizes in impact evaluations. Third, the distribution of agricultural inputs and extension support was not even between the treatment and control sub-counties of our study. Qualitative interviews conducted by the authors in April 2022 revealed that the political leadership in Gweri (which served as control sub-county) was found to be more active and engaged in attracting government support, including agricultural extension services, which may have influenced household perceptions of improved seeds in Gweri.

The mental model approach and especially the standardized elicitation method used in this study leads to high internal validity on respondents' perceptions due to relatively little researcher influence. Despite the narrow focus on one district in Eastern Uganda, we are confident that the context of our study – a rural area with predominantly customary land tenure and smallholder farming – may offer lessons for other regions in Uganda and other countries in sub-Saharan Africa. Customary land tenure, subsistence farming, undocumented land, and uncertain land tenure are found across many regions across sub-Saharan Africa. In addition, the land tenure intervention we study is part of a global project that has been applied in eleven countries across three continents, reaching more than 155,000 smallholder farming households (Land Portal, 2023).

Future research may include a repeated elicitation of mental models from the same respondents, including before and after an intervention, to study whether and how an individual's mental model changes over time and to capture potential timing effects linked to the tenure security intervention. Other adaptation measures could also be studied as outcomes of interest. Particularly interesting distinctions include adaptation strategies with different time horizons until benefits are reaped and adaptation strategies that are labor intensive versus capital intensive.

Our findings shed light on a long-standing land policy debate regarding the investment effect of secure land tenure, which is also relevant for the implementation of climate adaptation. Results suggest that the relevance of perceived tenure security and formal land rights varies across male- and female-headed

households. In light of these findings, targeted land tenure projects and policies should prioritize socio-demographic groups, particularly women, who place higher value on secure land tenure, as a strategic approach to fostering agricultural investment. If the primary aim is to increase agricultural investment, policies and projects beyond those with a land tenure focus may be more appropriate, such as policies or projects directly targeting households' financial means, which featured most prominently in the mental models.

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# Appendix

**Table A1: Comparison of characteristics across treatment and control households.**

| Statistic | Mean | | Df | T-stat | p-value |
|---|---|---|---|---|---|
| | Treatment households (N=97) | Control households (N=128) | | | |
| | (1) | (2) | (3) | (4) | (5) |
| Adaptation strategies currently practiced: | | | | | |
| Any type of improved seeds | 0.38 | 0.33 | 223 | -0.83 | 0.41 |
| Climate-resilient seeds | 0.31 | 0.27 | 223 | -0.72 | 0.47 |
| Drought-resistant seeds | 0.16 | 0.13 | 223 | -0.67 | 0.50 |
| High-yielding seeds | 0.12 | 0.11 | 223 | -0.33 | 0.74 |
| Early-maturing seeds | 0.21 | 0.19 | 223 | -0,35 | 0.73 |
| Crop rotation | 0.64 | 0.64 | 223 | 0.02 | 0.98 |
| Agroforestry | 0.14 | 0.18 | 223 | 0.71 | 0.48 |
| Intercropping | 0.64 | 0.64 | 223 | 0.02 | 0.98 |
| Plastic bottle drip irrigation | 0.09 | 0.12 | 223 | 0.76 | 0.45 |
| Land characteristics: | | | | | |
| Household feels tenure insecure | 0.09 | 0.12 | 214 | 0.59 | 0.56 |
| Household has a land certificate (CCO) | 0.35 | 0.05 | 223 | -6.13 | 0.00*** |
| Household has ongoing land conflict | 0.09 | 0.22 | 223 | 2.55 | 0.01** |
| Household has ever had land conflict | 0.49 | 0.45 | 210 | -0.57 | 0.57 |
| Farm size (in ha) | 2.02 | 1.45 | 223 | -2.94 | 0.00*** |
| Number of parcels owned | 2.27 | 2.09 | 217 | -0.60 | 0.55 |
| Household characteristics: | | | | | |
| Main income source is farming | 0.97 | 0.91 | 223 | -1.88 | 0.06* |
| Household owns livestock | 0.78 | 0.65 | 220 | -2.13 | 0.03** |
| Household sells no part of its agricultural production | 0.29 | 0.45 | 217 | 2.37 | 0.02** |
| Last year was bad in terms of food availability | 0.85 | 0.90 | 219 | 1.10 | 0.27 |
| Received remittances in the past 12 months | 0.21 | 0.16 | 216 | -1.00 | 0.32 |
| Received extension advice in the past 5 years | 0.48 | 0.44 | 214 | -0.53 | 0.60 |
| Household size | 8.73 | 10.10 | 218 | 1.71 | 0.09* |
| Head of household characteristics: | | | | | |
| Male | 0.76 | 0.81 | 222 | 0.95 | 0.35 |
| Age | 51.34 | 48.43 | 219 | -1.39 | 0.17 |
| No formal education | 0.13 | 0.10 | 219 | -0.67 | 0.51 |
| Ethnicity is Iteso | 0.58 | 0.98 | 223 | 8.92 | 0.00*** |
| Ethnicity is Kumam | 0.42 | 0.00 | 223 | -9.64 | 0.00*** |

Note: Columns 4 and 5 report results from unconditional t-tests of the equality of means between treatment households (i.e., households participating in the RELAPU land demarcation and registration project) and control households (i.e., households not participating in the RELAPU project), with * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Data source: AGRICA survey.

## Table A2: Description of complete set of drivers used in the M-Tool.

| Name of driver | Description |
|---|---|
| Tenure security | Tenure security captures the feeling of households that they are safe on their land and do not need to fear losing their land. |
| Land certificate | Land certificate refers to Customary Certificates of Ownership, the formal land titles households in Uganda can obtain for land held under customary tenure. |
| Credit access | Credit access is the ability to borrow money through loans for personal or business (e.g., farming) needs. |
| Changing climatic conditions | Changing climatic conditions refer to shifts in weather patterns and temperatures, affecting the usual growing seasons and conditions for crops in Uganda. |
| Expected benefit | Expected benefit refers to the anticipated usefulness of improved seeds. |
| Extension support | Extension support refers to information and trainings provided by the government or development actors, which educate farmers on good farming practices. |
| Extreme weather events | Extreme weather events refer to specific hazards, such as droughts or floods. |
| Financial capital | Financial capital refers to money and other assets that farmers use to generate wealth, invest, or fund various activities. |
| Gender | The gender of the household head refers to whether the person leading or representing the household is male or female. |
| Household size | Household size indicates the number of individuals living together in a single dwelling and sharing common resources. |
| Input costs | Input costs in agriculture encompass the expenses incurred for resources like seeds, fertilizers, pesticides, labor, and other materials essential for crop cultivation. |
| Knowledge | Knowledge refers to information, skills, and understanding acquired through learning and experience, enabling individuals to make informed decisions and solve problems in various aspects of life. |
| Labor availability | Labor availability denotes the presence and accessibility of workers or manpower for tasks and activities, indicating the potential workforce that can be utilized for various purposes, such as agricultural activities. |
| Recommendations | Recommendations refer to advice by family, friends and neighbors, e.g., on farming practices. |
| Soil quality | Soil quality refers to the ability of soil to support plant growth and provide essential nutrients, influenced by factors like texture, structure, fertility, and the presence of beneficial microorganisms. |

Source: The authors.

**Table A3: Comparison of mental models across treatment and control households, with full set of drivers displayed.**

| Driver | Frequency | | | | Rank | | Mean out-strength | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Treatment households (N=97) | Control households (N=128) | T-stat | P-value | Treatment households (N=97) | Control households (N=128) | Treatment households (N=97) | Control households (N=128) | T-stat | P-value |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| Financial capital | 0.87 | 0.94 | 1.83 | 0.07* | 1 | 1 | -0.08 | -1.34 | -3.80 | 0.00*** |
| Expected benefit | 0.81 | 0.85 | 0.74 | 0.46 | 2 | 3 | 2.04 | 1.84 | -0.79 | 0.43 |
| Extension support | 0.78 | 0.82 | 0.69 | 0.49 | 3 | 4 | 0.76 | 0.61 | -0.48 | 0.63 |
| Extreme weather events | 0.73 | 0.75 | 0.31 | 0.76 | 4 | 6 | -0.25 | -1.04 | -2.29 | 0.02** |
| Input costs | 0.71 | 0.88 | 3.12 | 0.00** | 5 | 2 | -0.78 | -1.30 | -1.60 | 0.11 |
| Changing climatic conditions | 0.62 | 0.65 | 0.46 | 0.65 | 6 | 8 | 0.60 | -0.23 | -2.08 | 0.04** |
| Knowledge | 0.61 | 0.67 | 0.99 | 0.33 | 7 | 7 | 1.15 | 0.85 | -0.95 | 0.35 |
| Soil quality | 0.58 | 0.80 | 3.81 | 0.00*** | 8 | 5 | 1.02 | 0.83 | -0.65 | 0.52 |
| Recommendations | 0.54 | 0.62 | 1.34 | 0.18 | 9 | 9 | 1.56 | 1.73 | 0.59 | 0.56 |
| Credit access | 0.45 | 0.58 | 1.86 | 0.06* | 10 | 10 | -1.32 | -1.51 | -0.52 | 0.60 |
| Gender | 0.37 | 0.38 | 0.06 | 0.95 | 11 | 11 | 0.75 | 1.25 | 1.14 | 0.26 |
| Tenure security | 0.33 | 0.30 | -0.40 | 0.69 | 12 | 14 | 1.22 | 0.87 | -0.78 | 0.44 |
| Labor availability | 0.30 | 0.32 | 0.34 | 0.73 | 13 | 13 | 1.34 | 0.44 | -2.02 | 0.05* |
| Household size | 0.20 | 0.34 | 2.47 | 0.01** | 14 | 12 | 1.37 | 1.07 | -0.77 | 0.45 |
| Land certificate | 0.19 | 0.12 | -1.44 | 0.15 | 15 | 15 | 0.28 | 0.33 | 0.08 | 0.94 |

Notes: Columns 3, 4, 9, and 10 report results from unconditional t-tests of the equality of means between treatment households (i.e., households participating in the RELAPU land demarcation and registration project) and control households (i.e., households not participating in the RELAPU project), with * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Data source: AGRICA mental models exercise and AGRICA survey.

**Table A4: Comparison of mental models across treatment and control households, with treatment sample restricted to households with land certificate.**

| Driver | Frequency | | | | Rank | | Mean out-strength | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Treatment households (N=34) | Control households (N=128) | T-stat | P-value | Treatment households (N=34) | Control households (N=128) | Treatment households (N=34) | Control households (N=128) | T-stat | P-value |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| Financial capital | 0.88 | 0.94 | 1.09 | 0.28 | 1 | 1 | 0.37 | -1.34 | -3.71 | 0.00*** |
| Extension support | 0.85 | 0.82 | -0.44 | 0.66 | 2 | 4 | 0.10 | 0.61 | 1.09 | 0.28 |
| Knowledge | 0.74 | 0.67 | -0.70 | 0.48 | 3 | 7 | 1.16 | 0.85 | -0.70 | 0.49 |
| Expected benefit | 0.74 | 0.85 | 1.60 | 0.11 | 3 | 3 | 1.52 | 1.84 | 0.82 | 0.42 |
| Input costs | 0.71 | 0.88 | 2.42 | 0.02** | 5 | 2 | -0.83 | -1.30 | -1.00 | 0.32 |
| Extreme weather events | 0.68 | 0.75 | 0.86 | 0.39 | 6 | 6 | 0.00 | -1.04 | -2.03 | 0.04** |
| Soil quality | 0.65 | 0.80 | 1.96 | 0.05* | 7 | 5 | 0.68 | 0.83 | 0.34 | 0.74 |
| Recommendations | 0.62 | 0.62 | 0.08 | 0.94 | 8 | 9 | 1.76 | 1.73 | -0.10 | 0.92 |
| Changing climatic conditions | 0.50 | 0.65 | 1.59 | 0.12 | 9 | 8 | 0.82 | -0.23 | -1.65 | 0.10 |
| Gender | 0.47 | 0.38 | -1.01 | 0.31 | 10 | 11 | 0.56 | 1.25 | 1.19 | 0.24 |
| Credit access | 0.38 | 0.58 | 2.05 | 0.04** | 11 | 10 | -1.08 | -1.51 | -0.73 | 0.47 |
| Labor availability | 0.35 | 0.32 | -0.36 | 0.72 | 12 | 13 | 0.75 | 0.44 | -0.49 | 0.63 |
| Tenure security | 0.29 | 0.30 | 0.12 | 0.91 | 13 | 14 | 1.40 | 0.87 | -0.78 | 0.44 |
| Household size | 0.24 | 0.34 | 1.20 | 0.23 | 14 | 12 | 0.88 | 1.07 | 0.34 | 0.74 |
| Land certificate | 0.09 | 0.12 | 0.47 | 0.64 | 15 | 15 | -0.67 | 0.33 | 0.68 | 0.51 |

Notes: Columns 3, 4, 9, and 10 report results from unconditional t-tests of the equality of means between treatment households (i.e., households participating in the RELAPU land demarcation and registration project) and control households (i.e., households not participating in the RELAPU project), with * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The sample is restricted to treatment households who acquired a land certificate. Data source: AGRICA mental models exercise and AGRICA survey.

**Table A5: Comparison of mental models across male- and female-headed households, with full set of drivers displayed.**

| Driver | Frequency | | | | Rank | | Mean out-strength | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Male-headed households (N=177) | Female-headed households (N=47) | T-stat | P-value | Male-headed households (N=177) | Female-headed households (N=47) | Male-headed households (N=177) | Female-headed households (N=47) | T-stat | P-value |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| Financial capital | 0.91 | 0.89 | -0.33 | 0.74 | 1 | 1 | -0.71 | -1.33 | -1.50 | 0.14 |
| Expected benefit | 0.84 | 0.83 | -0.10 | 0.92 | 2 | 3 | 2.01 | 1.62 | -1.30 | 0.19 |
| Extension | 0.80 | 0.81 | 0.10 | 0.92 | 3 | 4 | 0.85 | -0.03 | -2.29 | 0.02** |
| Input costs | 0.80 | 0.85 | 0.84 | 0.40 | 3 | 2 | -1.13 | -1.00 | 0.35 | 0.73 |
| Extreme weather | 0.75 | 0.72 | -0.31 | 0.76 | 5 | 5 | -0.69 | -0.76 | -0.17 | 0.86 |
| Soil quality | 0.73 | 0.60 | -1.86 | 0.06* | 6 | 7 | 0.85 | 1.00 | 0.39 | 0.70 |
| Knowledge | 0.66 | 0.60 | -0.76 | 0.45 | 7 | 7 | 1.18 | 0.07 | -2.84 | 0.01** |
| Changing climate conditions | 0.64 | 0.64 | -0.00 | 0.99 | 8 | 6 | 0.16 | -0.03 | -0.39 | 0.70 |
| Recommendations | 0.61 | 0.49 | -1.49 | 0.14 | 9 | 10 | 1.69 | 1.48 | -0.56 | 0.58 |
| Credit access | 0.51 | 0.55 | 0.47 | 0.64 | 10 | 9 | -1.43 | -1.65 | -0.52 | 0.60 |
| Gender | 0.38 | 0.34 | -0.48 | 0.63 | 11 | 13 | 1.13 | 0.50 | -1.15 | 0.26 |
| Household size | 0.30 | 0.21 | -1.17 | 0.24 | 12 | 14 | 1.13 | 1.30 | 0.34 | 0.73 |
| Tenure security | 0.30 | 0.38 | 1.09 | 0.28 | 12 | 11 | 1.02 | 1.06 | 0.07 | 0.94 |
| Labor | 0.29 | 0.36 | 0.89 | 0.37 | 14 | 12 | 0.92 | 0.47 | -0.85 | 0.40 |
| Land certificate | 0.14 | 0.19 | 0.96 | 0.34 | 15 | 15 | -0.08 | 1.33 | 1.88 | 0.07* |

Notes: Columns 3, 4, 9, and 10 report results from unconditional t-tests of the equality of means between male- and female-headed households, with * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Data source: AGRICA mental models exercise and AGRICA survey.

## Table A6: Comparison of characteristics across male and female-headed households.

| Statistic | Mean | | Df | T-stat | p-value |
|---|---|---|---|---|---|
| | Male-headed households (N=177) | Female-headed households (N=47) | | | |
| | (1) | (2) | (3) | (4) | (5) |
| Land characteristics: | | | | | |
| Household feels tenure insecure | 0.10 | 0.11 | 213 | 0.16 | 0.87 |
| Household has a land certificate (CCO) | 0.18 | 0.19 | 222 | 0.17 | 0.87 |
| Household has ongoing land conflict | 0.16 | 0.17 | 222 | 0.20 | 0.84 |
| Household has ever had land conflict | 0.45 | 0.55 | 209 | 1.14 | 0.26 |
| Farm size (in ha) | 1.72 | 1.62 | 222 | -0.40 | 0.69 |
| Number of parcels owned | 2.23 | 1.93 | 216 | -0.82 | 0.42 |
| Participated in RELAPU project | 0.41 | 0.49 | 222 | 0.95 | 0.37 |
| Household characteristics: | | | | | |
| Main income source is farming | 0.92 | 1.00 | 222 | 2.08 | 0.04** |
| Household owns livestock | 0.75 | 0.53 | 219 | -3.00 | 0.00*** |
| Household sells no part of its agricultural production | 0.37 | 0.40 | 216 | 0.37 | 0.71 |
| Last year was bad in terms of food availability | 0.87 | 0.91 | 218 | 0.88 | 0.38 |
| Received remittances in the past 12 months | 0.16 | 0.23 | 215 | 1.20 | 0.23 |
| Received extension advice in the past 5 years | 0.49 | 0.33 | 213 | -2.00 | 0.05* |
| Household size | 9.57 | 8.94 | 217 | -0.66 | 0.51 |
| Head of household characteristics: | | | | | |
| Age | 47.60 | 57.94 | 218 | 4.23 | 0.00*** |
| No formal education | 0.06 | 0.32 | 218 | 5.06 | 0.00*** |
| Ethnicity is Iteso | 0.80 | 0.85 | 222 | 0.84 | 0.40 |
| Ethnicity is Kumam | 0.19 | 0.15 | 222 | -0.68 | 0.50 |

Notes: Columns 4 and 5 report results from unconditional t-tests of the equality of means between male- and female-headed households, with * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Data source: AGRICA survey.