Agricultural Systems 217 (2024) 103912

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

Gender, agricultural risk perceptions, and maize seed systems: A case study of drought-tolerant maize varieties in Uganda

Astrid Mastenbroek [a,*], Tatiana Gumucio [b], Josephine Nakanwagi [c]

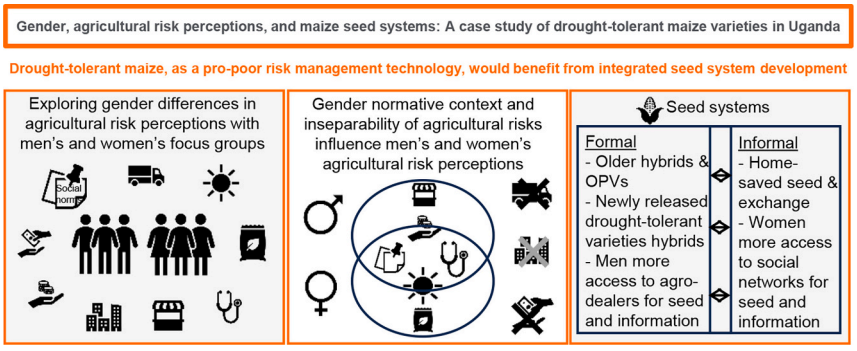
[a] Development Economics Group, Wageningen University, Wageningen, Netherlands
[b] Landesa, Seattle, United States
[c] Integrated Seed and Sector Development Uganda, Kampala, Uganda

HIGHLIGHTS

- Inadequate grasp of risks in agriculture and gendered normative context may hinder adoption of agricultural technologies.
- We explore gender roles, norms, and perceptions of risk in agriculture hampering drought-tolerant maize adoption in Uganda.
- Men and women have varying perceptions of production risks, health risks, social norm risks, and financial constraints.
- The formal maize seed system alone may not address the gender normative context and inseparability of agricultural risks.
- As a pro-poor risk-managing technology, drought-tolerant maize would gain from integrating formal and informal seed systems.

GRAPHICAL ABSTRACT

Graphical Abstract



ARTICLE INFO

Editor: Pytrik Reidsma
Guest Editor: Berber Kramer

Keywords:
Gender
Seed systems
Improved varieties
Uganda
Agricultural risks
Risk perception

ABSTRACT

CONTEXT: Drought-tolerant maize (DTM) varieties and other agricultural technologies can play an important role in maintaining crop production and livelihoods, yet their uptake remains low. Most research on risks in agriculture only considers climate risks as a barrier to adopting agricultural technologies. Farming communities face other agricultural risks related to health, finances, markets, and institutions. These risk perceptions may be different for male and female farmers.
OBJECTIVE: We explore the agricultural risk perceptions of male and female smallholder farmers, assessing gender roles and norms and their influence on risk perceptions. Subsequently, we discuss the implications of these perceptions and gender roles and norms on the uptake of drought-tolerant maize varieties in Uganda.
METHODS: We conducted a qualitative study with men's and women's focus groups in twelve villages in three districts in Uganda. We used participatory rural appraisal tools with each group to structure the discussions.
RESULTS AND CONCLUSIONS: Production risks, health risks, social norms, and financial constraints may play an important role in smallholder agricultural decision-making. These risks are inseparable and different for men's

* Corresponding author at: Development Economics Group, Wageningen University, 6708 PB Wageningen, Netherlands.
E-mail address: astrid.mastenbroek@wur.nl (A. Mastenbroek).

https://doi.org/10.1016/j.agsy.2024.103912
Received 4 September 2023; Received in revised form 16 February 2024; Accepted 28 February 2024
Available online 14 March 2024

and women's groups. Women tend to prioritize climate and crop management risks, while men place more weight on financial constraints. The perceived impact of health risks, risks related to social norms, and market risks vary across men and women in different districts. Dokolo reflects more traditional gender roles, while Iganga and Masindi note more contested gendered power over maize cultivation. The risk and concern ranking in Dokolo shows more similarity between men and women compared to Iganga and Masindi. Women tend to have less access to DTM varieties in the formal seed system, while they tend to have fewer resources to mitigate health and crop production risks. To reach and benefit more women with DTM varieties, we draw attention to access to information, bringing seed closer (potentially subsidized), gender transformative interventions, and investment in open-pollinated varieties disseminated through the informal seed system.

SIGNIFICANCE: Our research emphasizes the importance of considering multiple risks in agriculture when promoting resilient farming systems rather than focusing solely on climate risk. We also show the importance of applying a gender lens to these risks and the uptake of DTM varieties. Serving as an inclusive and pro-poor risk management technology, DTM would benefit from ensuring that the technology becomes available to male and female farmers in multiple seed systems, including formal seed systems (primarily hybrids) and informal seed systems (primarily open-pollinated varieties).

1. Introduction

Smallholders face not only weather risks but many other risks in agriculture, such as plagues, fluctuating output prices, and health shocks (de Janvry and Sadoulet, 2020). These sources of risks in agriculture are generally classified as production (including climate and weather-related), personal, market, financial, and institutional risks (Hardaker et al., 2015; Harwood et al., 1999; Osiemo et al., 2021). Of these, production risk, particularly climate change, has been high on the research agenda resulting in many climate-smart activities proposed to enhance resilience against shocks. A meta-data analysis of 3283 peer-reviewed studies about crops and livestock published between 1974 and 2019 shows that 66% of the studies focused on production risks alone, while only 15% studied a combination of more than one risk in agriculture (Komarek et al., 2020).

Effective risk management strategies and policies for agriculture require detailed analysis of multiple types of risks (Komarek et al., 2020), especially since smallholders' perceptions of risks are often interrelated (van Winsen et al., 2013). For example, smallholders may avoid risky agricultural investments because, in addition to production risks, they also may consider the risk of labor shortfalls and the risk of low grain prices, classified as background risks by economists. Background risks are those risks that farmers cannot insure against or avoid by taking some action, tempting households to reduce overall risk exposure (Fagereng et al., 2016). Different risks could thus interact and increase the level of risk aversion. Therefore, understanding these risk perceptions is essential to appreciate farmers' agricultural technology investment decisions (Huet et al., 2020).

Failure to appreciate the interplay of different risks and farmers' perceptions may result in overly optimistic adoption models and unrecognized barriers to adopting agricultural technologies. When faced with risk and uncertainty, smallholder farmers may apply risk-reduction strategies that act as disincentives to invest in agricultural technologies, mainly when no risk transfer instruments are available (de Janvry and Sadoulet, 2020; Hansen et al., 2019). They plan for the worst scenario by investing ex-ante in cropping systems that are less risky but also less profitable and thus under-invest in agricultural technologies (Hansen et al., 2022, 2019; Zúñiga et al., 2021). These choices may result in low-input-low-output cropping systems using home-saved seed.

Maize is important for the diets and incomes of smallholder farmers in sub-Saharan Africa (Prasanna et al., 2021), providing a large fraction of household food and income (Boucher et al., 2021). Forty percent of Africa's maize-growing areas face occasional droughts resulting in yield losses of 10–25% (Fisher et al., 2015; Wossen et al., 2017). Although drought-tolerant maize (DTM) varieties are important in maintaining production and protecting livelihoods given this weather risk (Boucher et al., 2021; Hansen et al., 2019; Teklewold et al., 2020; Wossen et al., 2017), the uptake of these varieties is slow (Chivasa et al., 2022; Fisher et al., 2015; Rutsaert and Donovan, 2020; Takahashi et al., 2020). These DTM varieties have a much higher yield potential and are generally more drought-tolerant than varieties traditionally grown by smallholder farmers (Boucher et al., 2021; Fisher et al., 2015; Prasanna et al., 2021; Simtowe et al., 2019; Wossen et al., 2017). While DTM addresses weather-related risks, other risks in agriculture can also play a role in seed investment choices. Boucher et al. (2021) state that the marginal cost of changing from improved varieties to DTM ones is low for farmers already purchasing maize seed. However, most smallholders rely on home-saved seed (Hoogendoorn et al., 2018; Mastenbroek et al., 2021) and would incur high replacement costs. In addition, DTM only protects against a single peril (drought).

Gender influences risk perception in farming communities partly due to socio-cultural norms concerning gender and gender-specific household roles and responsibilities. Empirical research shows that men and women have different preferences for selecting crops and varieties, whereby women consider food security and risk reduction, while men consider high yields (Rengalakshmi et al., 2018; Teklewold et al., 2020). For example, Smith, Barrett, and Box show that women's role in food preparation can influence their concern for food availability risk (Barrett et al., 2001; Smith et al., 2000). Timu and Kramer (2021) highlight several reasons why women are more vulnerable to climate-related production and income shocks. These include fewer options to manage risk because of less ownership and control over productive assets and limited mobility to access agricultural services due to time spent on reproductive tasks.

Although women play a crucial role in farming and food production, they often face more challenges in adopting agricultural technologies when compared to men (Meinzen-Dick et al., 2011). Fisher and Carr (2015) indicate that differential access to productive resources in Eastern Uganda contributes to men's greater tendency to adopt drought-tolerant maize than women's. Teklewold et al. (2020) show that women in Tanzania and Uganda, being more risk-averse than men, are less likely to adopt DTM varieties if they experience climate shocks or dry spells. Cullen et al. (2018) and Quinn et al. (2003), in their research with agriculturalists and pastoralists in Tanzania and Mali, also suggest that gender labor roles can influence risk perceptions, as risks associated with “natural capital” (i.e., land, weather, livestock disease) are perceived higher by men, while those associated with “human capital” (i.e., hunger, access to water, access to medical care) are perceived higher by women. These gender differences are usually overlooked in risk (perception) research, as shown in a global review by Duong et al. (2019). Understanding if and how risk perceptions differ by gender will allow better targeting of technologies to the needs of specific subgroups (Cullen et al., 2018).

In this study, we detail men's and women's agricultural risk perceptions and assess the gendered opportunity context influencing risk perceptions. Subsequently, we discuss the implications of our findings for the adoption of drought-tolerant maize varieties. The research question is, which agricultural risks and constraints do male and female

smallholders in Uganda identify that could pose (additional) barriers to adopting DTM varieties? To answer this question, we conducted a qualitative study with men's and women's focus groups in three districts in Uganda using participatory rural appraisal (PRA) tools. The PRA approach seeks community engagement through interactive sessions in a focus group setting. The approach empowers groups to assess and communicate their views and perceptions on various livelihood issues, generally from a gender-differentiated perspective (Mwongera et al., 2017). PRA tools help visualize, organize, and analyze these views and perceptions.

The gender lens uncovers several differences in risk perceptions. By highlighting these differences and drawing attention to the underlying gender roles and social norms, we contribute to the debate on strengthening the resilience of both male and female smallholder farmers. We take a smallholder livelihood perspective, which optimizes labor to smooth income and consumption (de Janvry et al., 1991; Harwood et al., 1999; Key et al., 2000; Murray-Prior, 1998; Vakis et al., 2004), and often coincides with the absence of institutional risk management options (Hansen et al., 2019). As a special case to the inseparability of consumption and production decisions, we find that the different agricultural risks are also inseparable in light of credit and insurance market failure. In addition to production risks, male and female smallholders are equally concerned with health-related risks, social norms and financial constraints.

Health-related agricultural risks are highest when food is scarce and agricultural input investments are needed. This is important because the hunger period coincides with the peak agricultural labor period, which coincides with the period when families have less money to spend. This inseparability of agricultural risks illustrates the importance of a multiple-risk management approach in agricultural technology adoption work. Further research is needed to understand the effect of multiple risks interacting with each other on levels of risk aversion and whether there are gender differences. Results would inform the need for expanding the scope of agricultural insurance packages, covering multiple risks, not just production risks, and whether such packages need to be tailor-made for men and women in different localities, addressing their risk perceptions and livelihood concerns.

Our research broadens the understanding of how smallholder farmers' gendered perceptions of risks shape potential barriers to adopting agricultural technologies, specifically drought-tolerant maize varieties in Uganda. We argue that the broader agricultural risk spectrum beyond climate risk alone could partially explain low adoption rates and high reliance on informal seed systems, especially by female smallholders. In addition, gender roles and norms tend to limit women's access to the formal maize seed system[1] for seed and seed information, while women rate the impact of crop production risks higher than men. Our findings imply that formal and informal seed systems are necessary to promote DTM as a pro-poor agricultural risk management opportunity. As a result, male and female smallholders may benefit from more deliberate integration of formal and informal maize seed systems.

The following chapter, methods and materials, contains the research design, the conceptual framework, a description of the research area, the participatory rural appraisal tools used, and the data analysis process. Chapter 3 describes the results, focusing on gender differences in roles, access to resources, decision-making, and social norms, followed by the results from the risk and concern ranking tool presenting gender differences and perceived impacts. Chapter 4 discusses the findings about the inseparability of agricultural risks, the gendered opportunity context, and their implications for integrated seed system development. The last chapter presents the conclusions.

2. Materials and methods

2.1. Research design and study area

This qualitative research is part of a larger project called “Promoting uptake of drought-tolerant maize varieties in Uganda” (PROMO).[2] The PROMO project aimed to investigate barriers to the uptake of drought-tolerant maize varieties developed by CIMMYT and partners under the ‘drought-tolerant maize for Africa seed scaling’ (DTMASS) project.[3] The premise of our research was that smallholders face a wide range of agricultural risks, not only climate or production risks. This qualitative research, conducted in April 2019, is a joint scoping exercise with male and female smallholder farmers to understand their livelihood risk perceptions and probe the nature of risks and gendered opportunity context that may inhibit them from investing in DTM seed. We chose three regions in Uganda covered by the DTMASS project and targeted one district in three different regions.

Our research focused on smallholder farmers in Uganda, with an average holding size of 1.35 Ha (UBOS, 2020). We are interested in their perspectives and whether there are gender and contextual differences. Due to budget and time limitations, we had to choose between the breadth and depth of the study. We opted for four villages in each selected district rather than multiple groups in the same village to explore gender differences between regions. In each village, we worked with one men's and one women's group, thereby creating groups with mixed socio-economic backgrounds and age brackets to capture a broad range of views. We conducted a deep dive with each group into different aspects of their farming systems and livelihoods using different PRA tools. We are mindful that male and female smallholders are not homogeneous categories and that more attention should be drawn to intersectionality to tailor pro-poor technologies to the needs of different sub-groups. This is a limitation of our study, and as a result, we tend to compare between men and women rather than providing a layered gender analysis.

We selected Iganga, Masindi, and Dokolo districts (Fig. 1). The choice was guided by regional spread, maize production intensity, climate, and promotional activities for drought-tolerant maize varieties in these districts. Based on the Uganda Bureau of Statistics (2017), Iganga was the leading maize-producing district in the eastern region with 303,262 metric tons (MT) annually, approximately 12,6% of the total production in Uganda. Masindi was selected because it is a large maize seed production district (61,715 MT) and the highest maize-producing district in the western region. In the northern region, we selected Dokolo district because it was an upcoming maize-producing district with vast agricultural land and a high potential for technology adoption. It produces approximately 16,921 MT annually (UBOS, 2017)).

Table 1 provides a brief overview of the agroecological characteristics of each district using livelihood mapping and zoning (Browne and Glaeser, 2010).

2.2. Conceptual framework

Our conceptual framework is the agricultural household framework using non-separability household models, where households combine production and consumption decisions. As a result of multiple market imperfections and farm constraints, these households cannot separate financial flows for (farm) profit-maximizing and subsequent household consumption (de Janvry et al., 1991; Dillon and Barrett, 2017; Kassie et al., 2020). However, if markets were complete and competitive,

[1] Farmers access seed through different seed systems, generally labeled as formal and informal, whereby the former partly relies on the private sector and the latter more on farmer networks. Mastenbroek et al. (2021) describe the Ugandan seed sector and its formal and informal seed systems in more detail.

[2] https://knowledge4food.net/research-project/gcp4-promoting-climate-resilient-maize-varieties-uganda/

[3] https://www.cimmyt.org/projects/drought-tolerant-maize-for-africa-seed-scaling-dtmass/

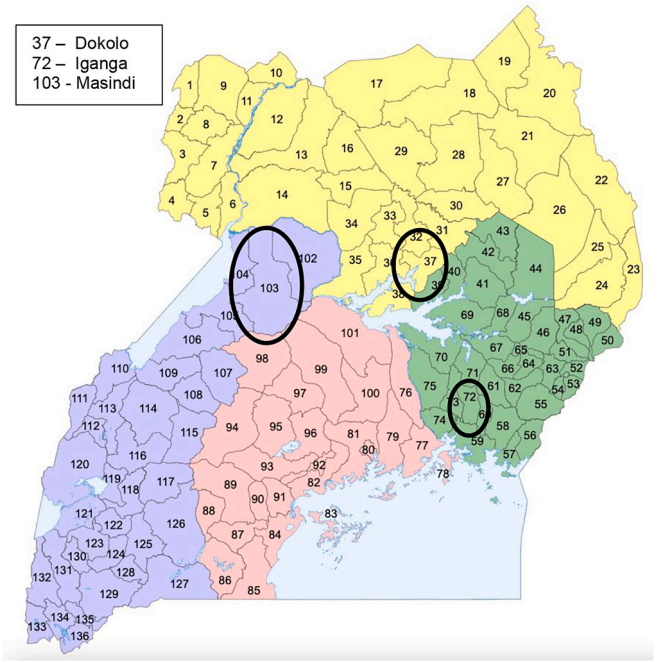


Fig. 1. Map of Uganda with districts of interest circled.
Source: By UNHCR - https://data2.unhcr.org/en/documents/details/83043, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=115943843 – accessed 20/05/2023

Table 1
Overview of agroecological characteristics per district.

District	Livelihood zone	Rainfall	Soil fertility	Climatic Hazards
Dokolo	Mid-north sesame, maize, and cassava	1000–1400 mm annually; 2 rainy seasons: mid-March – Mid-June & mid-July – mid-November	Soils are moderately fertile	Prolonged dry spells, crop and livestock epidemics, floods Infrequent (once in 5–10 years
Iganga	Southeastern maize, beans, Robusta coffee, and cattle	Not available	Not available	Prolonged dry spells, crop diseases, livestock diseases
Masindi	Bwijanga-Pakanyi sugarcane, maize and cassava	1270–1400 mm annually; 2 rainy seasons: May – June & August–November	Soils are relatively fertile	Prolonged dry spells (once every three years)

Source: Browne and Glaeser (2010).

households could buy and sell labor and land, and buy other inputs at independent equilibrium prices. In that case, we can examine production and consumption decisions as if they were different problems (Dillon and Barrett, 2017).

When markets do not function well, they generate transaction costs. If these are high, they may hamper smallholders from engaging in markets to buy or sell, and they depend (partly) on their production for consumption (Kassie et al., 2020). These market imperfections stem from institutional and infrastructural constraints that impede smallholders from fully participating in input and output markets. Dillon and Barret (2017) show general and structural input market failures in Uganda, not specific to any subpopulation or gender, making the concept of inseparability applicable to our case. Though markets are present and function competitively, they generate low welfare outcomes for some groups, leading to low input use as a sub-optimal resource allocation from a social perspective (Dillon and Barrett, 2017).

For smallholders who depend on agriculture, the inseparability of production and consumption decisions leads to agricultural risks affecting their production and livelihood simultaneously. The inseparability makes the endowment of a household predict input demand (Dillon & Barret, 2017). This is relevant because "[p]overty is about both the level of consumption and vulnerability. Households are especially vulnerable when they face risks that are large relative to their incomes (as is typically the case for poor farmers) and when these risks affect entire communities simultaneously (…). Farmers, keenly aware of this, may hold back on investment and thus miss out on opportunities for higher income" (Karlan et al., 2014, p598–599).

In our analytical framework, we distinguish between risks and constraints. Risks contain an element of uncertainty, a possibility to cause loss, and an effect of the risk (loss). A constraint is a certainty (permanent condition) that leads to sub-optimal outcomes. They are often related. The impact of a risk is determined by three variables: an event (hazard), a vulnerability, and an exposure. Constraints influence the level of vulnerability to risk and the ability to manage the risk (PARM, 2018).

To organize sources of risks and constraints, we use the agricultural risk categories classified by Harwood et al. (1999): production, market, personal, financial, and institutional. Like Osiemo et al. (2021), we include both risks and uncertainty in the 'risk' concept. We further subdivide these risks and constraints based on work done by the Platform for Agricultural Risk Management (PARM http://p4arm.org). We included one additional category mentioned by Siegel and Alwang (1999), 'social risks and cultural norms,' as we also expected barriers to the uptake of drought-tolerant maize related to this sphere. We added this category under personal risks to address concerns associated with cultural norms and social relationships. We also added a second category under financial risks to accommodate the budget constraint many smallholders face. Most groups referred to this constraint as "poverty". We purposefully added this category as groups frequently mentioned it.

We analyze these risks and constraints from the field-level perspective as we are interested in the perceptions of male and female community members. Table 2 describes the categories that we used in this study. If a category only contains risks, we refer to it as a risk. If a category only contains constraints, we refer to it as a constraint. Finally, if a category includes risks and constraints, we refer to it as concerns.

Smallholder farmers face two types of production risks. The first relates to all management and operational decisions for the farm, including all choices on what inputs (land, labor, capital) to use during crop production and post-harvest handling. The second is the subcategory 'weather, biological and environmental related risks,' which we colloquially call 'climate' risks. However, this subcategory is broader than just climate and weather variability, as shown in Table 2.

Drawing upon Kabeer (1999) and the Enabling Gender Equality in Agricultural and Environmental Innovation (GENNOVATE) project (Badstue et al., 2014), we consider women and men have varying capacities to demand and adopt new technologies due to differing constraints on agency and opportunities available to them. GENNOVATE notes that agricultural research for development approaches can "often overlook the ways in which social norms, attitudes, and distributions of power and resources differentially frame women's and men's perceptions of, and capacities to seize, opportunities" (Badstue et al., 2020, p. 541). Gender norms, referring to societal expectations and roles based on gender, women's ability and willingness to express their agency influence how women engage with and adopt agricultural technologies. Introducing new technologies could also involve renegotiating power relations to secure benefits for men and women (Farnworth et al., 2020). Therefore, our analysis considers factors such as gender roles, control over productive resources, voice in agricultural decision-making

Table 2
Description of risk and constraint categories in the agricultural sector.

Cluster of concerns	Category	Description
Production – uncertain natural growth processes[a]	Management and operational risks & constraints	Risks: Uninformed or poor management decisions in asset allocation, choices of crops, and seed, sowing time, equipment; use of inputs, planning errors, breakdowns in equipment, inability to adapt to changes[b] Constraints: availability of land, skills, and equipment[c]
	Weather, biological, and environmental-related risks	Periodic deficit or excess rainfall or temperature, (hail) storms, changes in cropping patterns, crop and livestock pests and diseases, and contamination and degradation of natural resources[b] and climate change
Market – price, costs, market access[a]	Logistical and infrastructural risks & constraints	Risks: Changes in access (physical or economic) to transport, communication, energy, degraded transport, or energy infrastructure due to physical destruction or lack of maintenance. Delays and disruptions of charges along the value chains[b] Constraint: availability of roads, markets, and enterprises[c]
	Price risks	Fluctuations in output prices due to different causes, such as changes in national, regional, or international supply and/or demand that impact markets, changes in demand for quantity and/or quality attributes, changes in food safety and production requirements[b]
Personal – human health and personal relationships[a]	Health risks	Health risks for farming households and farm workers; production failure for health and/or food insecurity reasons[b]
	Social risks and cultural norms	Risks associated with social ties and social networks[d] (p8) Concerns related to needs for social support, safety nets, and welfare services. Social or culturally influenced threats such as intra-household and intra-communal conflicts (e.g., on land ownership, social norms on labor division, domestic violence)[c]
Financial - associated with how the farm is financed & additional variability of cash flow[a]	Financial constraints (Poverty)	Concerns related to general poverty, generic lack of money in households, low levels of cash flow within semi-subsistent households[c]
	Access to credit and other financial products	Risks related to the financing of the farm; access, costs, collateral, and/or grace period of financial products, availability of financial products, and suitability of financial products to the agricultural sector[a]
Institutional – (unpredictable) changes in policies and regulations[a]	Institutional risks & constraints	Risks: Changing or uncertain policies and weak enforcement of those monetary, fiscal/tax, and financial policies; unpredictable regulatory and legal measures; trade and market disruptions; uncertainty in land tenure, governance uncertainty; conflicts and political or labor disputes, corruption, weak institutions[b] Constraints: lack of employment opportunities and education, school drop-outs[c]

[a] Komarek et al. (2020) p3.
[b] TOR PARM Risk assessment Table 1 (PARM, 2014).
[c] Our own description.
[d] Siegel and Alwang (1999).

processes, and local normative structures surrounding gender relations to assess farmers' risk perceptions and corresponding influences on agricultural investment choices. Furthermore, we recognize that different groups of women and men can experience challenges in adopting drought-tolerant maize due to traits in addition to gender, such as ethnicity, wealth class, and life stage (Carr and Thompson, 2014; Fisher and Carr, 2015). However, due to project-related and other limitations, we compared trends between aggregate groups of women and men for this study.

Perceptions of agricultural risks influence farmers' responses to these risks (Duong et al., 2019). Risk perceptions refer to people's judgment and evaluation of shocks/hazards to which they may be exposed (Rohrmann, 2008). They can best be understood as a network of interrelated notions of uncertainty, their effects, and uncertain outcomes (van Winsen et al., 2013). Such perceptions steer decisions about which risks are acceptable and which are not. These appraisals are a complex result of the hazard, personal philosophy, and experiences embedded in culture, norms, and value systems (Rohrmann, 2008).

2.3. Participatory rural appraisal tools

To enable us to answer the research questions, we applied qualitative research methods. We worked with separate men's and women's groups to enable us to compare the responses from men and women and note gender differences. We used Participatory Rural Appraisal (PRA) tools to secure the maximum engagement of community members. The tools used for this research are a historical timeline, village resource mapping, four cells analysis, seasonal calendars, focus group discussions on maize, and matrix scoring on major risks and concerns. All tools were selected to address different aspects of the gender analysis and to map the risk perceptions and subsequent barriers to the uptake of DTM varieties. In this section, we briefly describe the tools. More details can be found in Appendix 1 in the supplementary data containing the facilitator's instructions.

A historical timeline is a participatory tool that identifies major events in the community and how these events affect livelihoods over time. We focused on how events affected agricultural development in the communities. The tool covered weather variability and familiar drivers/causes of changes in climate, frequency of severe climate events and how communities cope with them, relevant developments in infrastructure, important initiatives to support crop production and seed systems, and other events that affected agricultural development in the community.

A seasonal calendar explores seasonal patterns (e.g., gender-specific

workload, diseases, income, expenditure, etc.). The objective is to map the seasonality of agricultural and non-agricultural workload, food availability, human diseases, gender-specific income and expenditure, water sources, forage, credit, and holidays. We inquired about the most critical activities associated with cultivating maize and one other main crop, and the household and income-generating activities. We listed the month they occurred the previous year to keep the exercise concrete and easy to recall. The tool captured the productive and reproductive tasks, who is responsible for that task (women, men, girls, or boys), who makes decisions about that task, and what equipment is used to carry out the task. In addition, we documented who controls the income generated from these activities. We also collected information on what time of year sickness peaks, when food and money are scarce, and whether borrowing options exist.

The four-cell analysis tool is used to make a quick inventory of crop coverage in the village. It uses two key variables: production area and the relative number of households growing the crops or varieties. These variables are organized into four different cells (a) crops or varieties grown by many households in large production areas, (b) crops or varieties grown by many households in small production areas, (c) crops or varieties grown by few households in large production areas, and (d) crops or varieties grown by few households in small production areas. The tool gives us insight into what crops are commonly grown, reasons for placing crops in their particular cell, their role (food, cash, or both), and what role maize plays in the farming systems.

The focus group discussion on maize seed buying behavior is used to understand why smallholder farmers generally do not buy quality seed from agro-dealers and seed companies. We probed the reasons farmers provided in surveys (for example, the seed is expensive, no access to seed, and insufficient information). We collected data on primary seed sources, decision-making in seed selection, trust in different seed sources, knowledge of hybrids and DTM varieties, and fertilizer use.

The risk and concern ranking tool helps to identify the risks and constraints farmers face related to agriculture and assess their perceptions of the most pressing ones. Rather than using the predefined risk categories described in the conceptual framework, the groups started by brainstorming about the concerns/problems they faced in providing for the family. These were listed on a flip chart (in a table). Next, up to five risks and constraints were documented. We used a matrix to conduct pairwise ranking, comparing each of the five concerns against the others. We then counted the number of times a concern was listed in the matrix and ranked them based on the frequency. Eight out of 12 men's groups and six out of 11 women's groups were consistent[4] in their ranking. For all groups, except one women's group, the highest rank (rank 1) was consistently chosen over other concerns, and for most groups, the second and third ranks were also consistent. Once the ranks were determined, the ranked concerns/problems were transferred to a table using flip charts. Next, the groups discussed the severity of the effects of each concern using the question: How bad are the effects of the concern/problem, high, medium, or low? Finally, the groups indicated whether the concern was common or not.

2.4. Fieldwork

The study was conducted in twelve villages, four in each district, in April 2019. One men's and one women's group were interviewed in each village. The groups comprised smallholder farmers of different age brackets, representing young and older farmers. A facilitator and enumerator conducted a session with each group in the local language. The agricultural officer employed by the Ministry of Agriculture mobilized the participants and supported the data collection process. Each group session lasted around 4–5 h. The facilitators worked with flipcharts and markers to visualize the tools with the group members. In addition, the information was recorded on answer sheets by the enumerators. We conducted a three-day training for the facilitators and enumerators and a pre-test in Mukono district. More information on the fieldwork process is provided in Appendix A, supplementary information.

2.5. Data analysis

Once the fieldwork was completed, the facilitators and enumerators documented the data at the group level and put the information in village-level reports using a fixed format. We analyzed the data per tool manually and aggregated the data from the group to the village to district level for men's and women's group responses. We synthesized the information and trends at the district level and by men's and women's groups to present a gender and a geographical lens.

The risk and concern ranking underwent additional manipulation, which we describe here. During data analysis, we categorized the concerns/risks/issues mentioned according to the different risk and constraint categories described in the conceptual framework (Table 2). A group could have more than one response in a category, as some concerns fit in the same category.

We worked with four men's and four women's groups in each district. Each group listed (up to) five concerns. As a result, in each district, both men's and women's groups ranked in total 20 concerns, except in Dokolo, where one women's group listed only four concerns (resulting in 19 ranked concerns), and in Iganga, where a women's group did not conduct the exercise due to time limitations (resulting in 15 ranked concerns). The data were analyzed using Excel and STATA.

We calculated the perceived impact by multiplying rank times severity of the concern/risk as follows. First, we gave a weight to the rank (rank 1 received a weight of 5 points, going down to rank 5, which received the lowest weight of 1 point). Then, since the groups indicated the severity of the risk/concern in terms of low, medium, and high, we assigned a second weight: 1 point for low, 3 points for medium, and 5 points for high. These were multiplied and averaged by the number of responses, giving the scores for each category (rank * severity). These scores ranged from 1 to 25, with 25 being the highest impact. We then ran a simple regression to assess the impact and test if there are gender and district differences in these categories. We clustered the standard errors by group ID.

3. Results

This chapter presents the results from the group discussions and PRA tools. We briefly describe the seed systems used and highlight the gender differences. We then analyze the gender differences in roles, access to resources, decision-making power, and socio-normative environment using the information provided by the different tools. Subsequently, we present the main risk and constraints ranking results and highlight the gender differences.

3.1. Maize seed systems

Results from the four-cell analysis show that the smallholders have diversified cropping systems, which spreads production and income risks. Both men's and women's groups in all villages mention that many farmers grow maize for food and income. This is not surprising considering that we selected maize-growing districts.

Results from the historic timeline on major crop and seed system initiatives document initiatives by government extension and input distribution programs (NAADS, Operation Wealth Creation) and NGOs. Some men's and a few women's groups indicate that these initiatives linked to access to new seed varieties resulted in higher maize yields, easy access to extension services, and better food security. More men's

[4] Consistency means whether a group ranked the concerns in a logical order. Thus, when rating concern 1 more important than concerns 2 and 3, concern 3 should be rated lower than concern 1.

groups in Masindi and Iganga report receiving extension services than men's groups in Dokolo and all women's groups.

Results from focus group discussions on maize seed show that men's and women's groups mention five and eight varieties as most common in their villages. Men and women in all districts mention Longe 5 (an open-pollinated variety (OPV)), Longe 10H (hybrid), and local varieties as the most common maize varieties grown. Longe 5 and Longe 10H have frequently been part of free government and NGO seed distributions, which may explain why groups could mention these variety names. These older maize varieties are relatively more susceptible to droughts, pests, and diseases than the recently released drought-tolerant varieties. In Uganda, all varieties released from 2012 onwards are drought-tolerant hybrids; no open-pollinated varieties were released from (public) breeding institutes.

Groups mention that farmers access seed from formal and informal seed systems. Compared to other districts, men and women in Dokolo list informal sources more often than formal ones. In Iganga men mention formal sources more frequently than women. In Masindi, we note no gender differences, and both sources are equally mentioned. Some farmers buy seed from agro-dealers in at least half of the villages. Levels of trust in agro-dealers vary between groups and group members. Groups indicate that getting high-yielding varieties is the main reason for buying seed from agro-dealers. In contrast, groups mentioned the seed price and fear of buying counterfeit/fake seed as the major deterrents.

Apart from women's groups in Dokolo, the other groups tend to know what hybrids are. At the same time, it should be noted that women in Dokolo mention Longe 10H as one of the most common varieties in the village, indicating an information gap in labeling. Most groups do not know the yield potential of these varieties, with women estimating lower yield potentials.

Major deterrents for using hybrids are lack of funds, seed price, and the need for fertilizer, with women's groups more often mentioning lack of funds and men's groups mentioning more often high seed price. Drought-tolerant maize varieties are less known than hybrid seed by women, except for women in Masindi. Across districts and groups, reasons for not buying DTM are high seed prices and insufficient knowledge about DTM, the latter particularly mentioned by women. We note that only three groups mention the recently released drought-tolerant hybrids.

Groups indicate that the primary sources of information about maize varieties were NGOs, government, radio messaging, fellow farmers, and personal experiences, whereby we note that women's groups indicate that women have less access to extension services than men. About half the women's groups mention relying on fellow farmers, while none of the men's groups mention this. Men mention support from government, NGO, or seed company extension workers in variety selection more often than women.

3.2. Gender analysis

The results of the seasonal calendar tool illustrate the gendered power dynamics in maize cultivation and their variation across the three districts concerning gendered perceptions of power and control at key points along the maize value chain. While men's and women's groups tend to indicate that both women and men participate in maize seed sourcing and buying and are responsible for the decision-making over it, women's groups in Iganga note that women alone participate in maize seed sourcing and buying and that they alone make decisions over it. Men's and women's groups also tend to note that both women and men participate in maize marketing and make decisions about it. However, results from men's and women's groups from Iganga district suggest a disparity in perceptions of responsibility and control over sales, with men's groups in Iganga highlighting that men alone make decisions over sales and women's responses from Iganga showing some perceptions of women's sole control over sales decision-making.

In Iganga and Masindi districts, men's groups highlight that men alone control income from maize sales. In comparison, women's groups' responses tend to vary across Iganga and Masindi (noting men alone, women alone, and both women and men). Results from Dokolo district also highlight a gender disparity in perceptions of maize income control, with women's groups emphasizing that men alone control the income from maize sales, and men's groups tend to note that both women and men have maize income control.

Results from the seasonal calendar and other tools on discussions of typical male and female activities show more gender-inappropriate behaviors for women than men, suggesting that norms can be more constraining for women than men. However, district-specific trends also suggest variation in how constraining norms are in practice, dependent on the context and sphere of control being influenced. Women's and men's groups in Masindi may agree more about women's and men's appropriate roles than in other districts. Moreover, women in Masindi tend to note that men and women share home-care responsibilities like meal preparation and caring for sick family members. In contrast, men's and women's responses in Dokolo tend to coincide in affirming the rigidity of gender-specific, socially ascribed roles. For example, although women's and men's groups in Masindi and Iganga tend to note that there were no typically female activities that would be inappropriate for men, women and men in Dokolo mention several such activities, including preparing and serving meals. Women's and men's groups in Iganga and women's groups in Masindi more often report marital issues as concerns compared to other groups in other districts. Although additional research is necessary, coupled with the findings of disagreement between women's and men's perceptions of women's autonomous control over maize sourcing and sales, the results suggest tension and potential male resistance to assertive roles women seek in maize cultivation in Iganga and possibly Masindi.

Results from other PRA tools (resource mapping, four-cell analysis, and maize focus group discussions) illuminate gendered control over other assets, resources, and information. Across districts, both men's and women's responses highlight that men control land. More opportunities for shared control by women and men are noted for other natural resources; however, some women's groups report shared control more often than men report shared control. Women also rarely make land use decisions independently; results show that men alone or both men and women make land use decisions. Who in the household controls income from productive activities depends on the activity and the context; however, women report autonomous control over income-generating activities such as mat-making and tailoring. Results suggest women may have less access to extension services and agro-dealers than men. In addition, men tend to know more about hybrid maize and drought-tolerant seed than women, except for women in Masindi, suggesting men's greater access to information on agricultural technologies.

Results from the seasonal calendar show that the hunger period coincides with the peak agricultural labor period. This is also the period when sickness is common. This means that during the peak agricultural period, when family labor is needed to cultivate crops, men and women may be physically weakest due to food scarcity and sickness. This period also overlaps with households having less money available (to buy food and pay for medical care).

Other results highlight women's role in homecare. In Dokolo and Iganga and, to a lesser extent, in Masindi, women tend to be responsible for most of the reproductive work, including caring for the sick, as well as for crop production and some forms of income generation. Results from the four-cell analysis also show that women may seek to derive a dual purpose (subsistence and commercial) from more crops than men, while in some cases, men may focus more on the cash purpose/value of crops.

In sum, the gender analysis provides an important context for assessing farmers' risk perceptions. The analysis shows contested, gendered power over maize cultivation in Iganga, with women and men active in key roles and responsibilities for its cultivation across districts.

Compared to men, women may face limited access and control over major resources like land, monetary income, agricultural training, and technological information. Some normative shifts are occurring, for example, around who is responsible for homecare amongst villages in Masindi.

3.3. Risk, constraints, and perceptions

Table 3 provides an overview of the constraints and risks reported by men's and women's groups in the districts, irrespective of the ranking. Forty percent of the issues are constraints, while 60 % are classified as risks associated with agriculture and livelihoods. Health-related concerns are most frequently mentioned, followed by financial constraints and social norm risks, and only then climate risks.

The health risks include human diseases, famine, and food shortage. Lack of food and famine are health issues because hunger affects the ability to work and increases the chances of getting sick. Therefore, these directly affect the household's capabilities to manage their agricultural risks. Groups mention access to water and health facilities as health constraints.

In the climate category, all mentioned issues are associated with risks: droughts, other weather-related risks, pests, and plant diseases. Under crop management, constraints include land shortage and insufficient skills and equipment, while seed quality and soil fertility are considered risks. All price risks involve uncertain output market prices, with all men's groups in Masindi mentioning the fluctuating and low maize grain prices.

The financial category encompasses poverty and lack of money, with no mention of access to credit or other financial products. The social norms category includes risks associated with domestic tension and violence, immorality, insecurity, and mistrust amongst partners. We specifically note the district differences related to domestic tensions and violence. Only one men's and one women's group in Dokolo mention domestic violence, while in Iganga, three men's and two women's groups note these, and in Masindi, all women's groups and none of the men's groups.

Institutional constraints include unemployment, illiteracy, and lack of education, while the institutional risk category includes only one mention of bad leadership. Infrastructural constraints highlight the absence of roads, physical markets, and shops. No logistical concerns are mentioned in this category.

Fig. 2 illustrates how men's and women's groups perceive the severity of the effects of the concerns if they materialize. We display only those pie charts with at least three responses for both men's and women's groups. Men's and women's groups classified 55% and 74% of the concerns as having severe consequences, respectively. We observe gender differences in the crop management, health, and financial categories, whereby crop management (though a small sample) and health are most noticeable. For health and crop management concerns, women rate the effects higher than men, while men rate the effects higher for financial constraints. In Masindi, 73% of the responses are in the high severity category, compared to 60% in Dokolo and Iganga. In line with contested gender power over maize cultivation discussed in the previous section, groups in Iganga perceive the effects of social norm risks as most severe, followed by Masindi and Dokolo.

Table 4 summarizes the perceived impact of agricultural concerns on the livelihoods of those groups that mention those concerns. We only display results for categories with multiple responses for men's and women's groups. Women's groups mention climate risks more often than men's groups. When we compare groups that mention them, women and men perceive the effect of a climate shock equally and the highest amongst all categories. Women rank crop management risks and their impact much higher than men. Men mention health-related concerns more often than women, while women perceive the severity of disease and food insecurity as higher. As a result, women who mention health-related concerns perceive the impact as significantly higher than men. Men rank financial constraints higher than women, with noticeable differences in the first two ranks. Nonetheless, men and women equally perceive the severity of the constraint as high. As a result, men who mentioned financial constraints perceive the impact as high, while women perceive the impact as a little lower. All men's groups in Masindi and one in Dokolo mention output price risks, while only one women's group lists price risks. Those men's groups mentioning price risk perceive the impact of output prices as moderate. Using a multivariate logistics regression, we checked whether men's or women's groups were more likely to mention a particular category more frequently. This was not the case. Overall, summarizing Table 4, women perceive a relatively higher impact of crop production and health risks, while men perceive a somewhat higher impact of financial constraints and price risks. Men and women perceive the impact of climate risks as equally high and social norm risks as equally moderate.

Table 4 compares the gender differences in impact scores based on the number of responses (N). Meanwhile, Table 5 below shows the average scores for each category amongst men's and women's groups for each district (total score per category and district divided by the number of men's or women's groups in that district (N)). While Table 4 shows some noteworthy gender differences, Table 5 cautions us against broad gender generalizations, highlighting distinct perceptions between men's and women's groups across the districts. In the subsequent paragraphs, we explore some of these differences, drawing connections to the results presented in sections on maize seed systems and gender analysis.

Table 3
Constraints and risks by men's and women's groups and district.

Constraints & Risk	Gender		District			Total
	Men's group	Women's group	Dokolo	Iganga	Masindi	
Climate	4	8	5	6	1	12
Management	3	6	6	2	1	9
Price	5	1	1	1	4	6
Health	**22**	**15**	**16**	**8**	**13**	**37**
Social	6	10	3	4	9	16
Financial	11	10	6	6	9	21
Institutional	8	1	1	5	3	9
Infrastructural	1	3	1	3		4
Total	*60*	*54*	*39*	*35*	*40*	*114*

Constraints	Gender		District			Total
	Men's group	Women's group	Dokolo	Iganga	Masindi	
Climate						
Management	2	4	4	1	1	6
Price						
Health	5	5	4	1	5	10
Social						
Financial	**11**	**10**	**6**	**6**	**9**	**21**
Institutional	8		1	4	3	8
Infrastructural	1	3	1	3		4
Total	*27*	*22*	*16*	*15*	*18*	*49*

Risk	Gender		District			Total
	Men's group	Women's group	Dokolo	Iganga	Masindi	
Climate	4	8	5	6	1	12
Management	1	2	2	1		3
Price	5	1	1	1	4	6
Health	**17**	**10**	**12**	**7**	8	**27**
Social	6	**10**	3	4	**9**	16
Financial						
Institutional		1		1		1
Infrastructural						
Total	*33*	*32*	*23*	*20*	*22*	*65*

Note: Bold numbers represent the highest frequency per category and column.

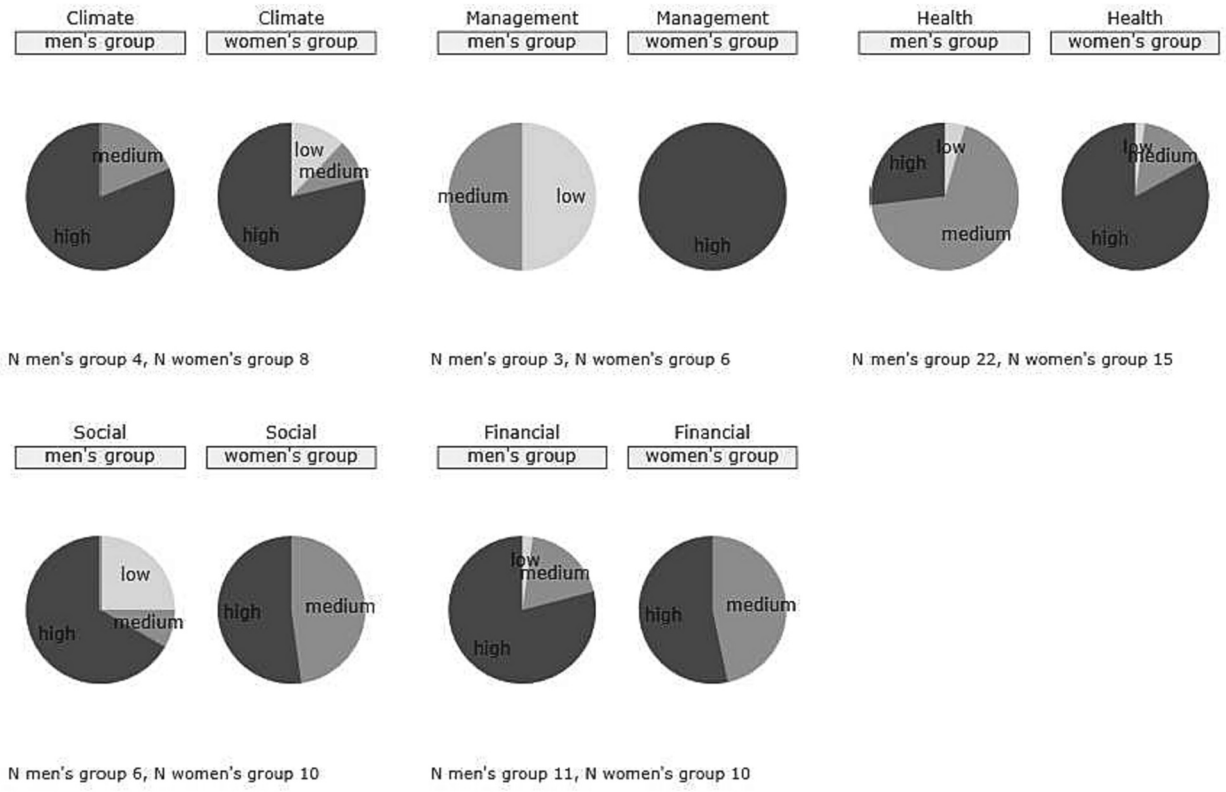


Fig. 2. Rating of the severity of effects of the risks and constraints by category and gender.

Table 4
Perceived impact of risk in agriculture on livelihoods (rank * severity).

	Impact Climate	Impact Crop management	Impact Health	Impact Social	Impact Financial
Female	−0.63	10**	3.97*	1.63	−5.53^{+}
	(2.67)	(2.44)	(1.74)	(3.21)	(2.68)
constant	18.5***	6.67***	10.5***	7.67*	17.7***
	(2.23)	(0.91)	(1.03)	(2.84)	(2.01)
N	12	9	37	16	21

Standard errors in parenthesis and clustered by group ID, $^{+}$ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, score ranges from 1 to 25, with 25 being the highest impact. N = number of observations.

Health risks relate to both the role of provider for the family, paying medical bills, and the role of caregiver, attending to the sick. Depending on the food availability and disease pressure, this may affect men and women in different districts differently. We observe variation in the perceived impact of health risks between men's and women's groups in different districts. Only women in Dokolo and men in Masindi and Dokolo rate the impact as high. This is contrary to the overall rating in Table 5, suggesting an equally high impact, and Table 4, suggesting a significantly higher impact for women than men who mention health risks. Examining the ranking of women's groups in Iganga and Masindi, other concerns take precedence over health risks. In Iganga, crop production risks and infrastructural concerns are deemed higher, while in Masindi, risks related to social norms and financial constraints are prioritized.

The risk and concern ranking shows more similarity between men's and women's responses in Dokolo than in Masindi and Iganga. Men's and women's groups in Dokolo share similar concerns in the risk and constraint ranking, with health concerns topping the list, followed by financial, climate, and crop management concerns. Compared to other districts, we note that men's and women's groups in Dokolo mention extension services less frequently and use of informal seed sources more frequently. This may relate to the perceived impact of crop management and climate concerns by both men's and women's groups in Dokolo. Also notable is that men's and women's groups in Dokolo rate the impact of the social norm category comparatively lower than groups in other

Table 5
Average score for each category for men's and women's groups by district.

	Dokolo		Iganga		Masindi		Total	
Category	Men's groups	Women's groups	Men's groups	Women's groups	Men's groups	Women's groups	Men's groups	Women's groups
Climate	10.0	12.3	8.5	23.0	–	6.3	6.2	13.0
Crop management	5.0	11.3	–	10.0	–	6.3	1.7	9.1
Price	2.5	–	–	1.0	15.5	–	6.0	0.3
Health	19.0	26.8	14.3	6.7	24.5	7.5	19.3	19.7
Social	1.3	3.0	6.5	3.3	3.8	17.8	3.8	8.5
Financial	13.0	10.0	21.3	7.0	14.5	15.3	16.3	11.1
Institutional	0.5	–	10.0	1.7	6.3	–	5.6	0.5
Infrastructural	0.8	–	–	14.3	–	–	0.3	3.9
Number of groups	*4*	*4*	*4*	*3*	*4*	*4*	*12*	*11*

Note: The minimum score for a concern is 1 and the maximum score is 25. Some groups mentioned more than one concern in a category.

districts. At the same time, we note more stringent norms and traditional role patterns in Dokolo, which appear less contested.

In Iganga, women's groups highlight the highest impact of climate risks, followed by infrastructural constraints (absence of shops, markets, and roads). They also mention informal seed sources more often and access to extension services less often. In addition, we also note contested responses between men's and women's groups on women's participation in decision-making and control over income. Though highly speculative, women in Iganga might feel constrained by the informal seed sources and may desire closer access to shops and markets for greater control over their productive tasks, and managing climate and crop risks. In line with the gender role of providing for the family, men perceive a higher impact of financial concerns. While contested responses exist over agricultural decision-making and income control in Iganga, women perceive the impact of social norms similarly to those in Dokolo. Men in Iganga perceive the impact higher than women in Iganga and men in Dokolo and Masindi, yet ranking them lowest of the mentioned categories.

Compared to women's groups in Dokolo and Iganga, women in Masindi perceive a lower impact of crop management and climate risks. They mention knowledge of DTM more often than women in other districts. Although we notice shifting reproductive gender roles in Masindi, women there perceive the highest impact of the social norm risks, surpassing those in other districts and all men's groups.

4. Discussion

Following Hansen et al. (2019), DTM varieties are a pro-poor technology benefiting smallholder farmers in their idiosyncratic risk management. As summarized by Kramer and Trachtman (2023), the typically identified barriers to seed adoption include mismatch between financial flows, production risks, and lack of information. Our results add a broader risk spectrum and an engendered opportunity context to the barriers of uptake. We first discuss the gender roles, norms, and risk perceptions in relation to access to DTM and place our findings within existing literature. Then, we discuss the inseparability of risks and constraints and relate this to risk aversion and broadening the scope of agricultural risk management interventions to support the uptake of DTM technologies in the formal seed system. The last section discusses how DTM could become more inclusive in terms of access to genetic gains, integrating the strengths of formal and informal seed systems.

4.1. Gender, risk perceptions and uptake of DTM varieties

In line with Voss et al. (2021) and others, our gender analysis shows that maize is neither a women's nor a men's crop and is grown for household food and income generation. Our findings show that women might not always have the final say in seed-sourcing and land use decisions, but they play a substantial role in decision-making. We note differences between women's and men's groups concerning women's involvement in decision-making processes, which could suggest that women and men have different perceptions of how household decisions are carried out. This aligns with other research like Acosta et al. (2019).

Based on the risk perception analysis alone, women ought to be just as interested as men, if not more, in adopting DTM to mitigate several risks, including those related to crop management, health, and climate. However, the gendered opportunity context can disfavor women's technology adoption compared to men. Our results indicate that women, except those in Masindi, are less aware of DTM varieties, generally disseminated through the formal seed system. One of the reasons may be that the sources of information for women are often skewed toward family and friends and for men toward extension services and agro-dealers (Fisher et al., 2019; Voss et al., 2021). This aligns with our findings that women have less access to agro-dealer shops for seed and information. Simtowe et al. (2019) found that relying on social networks for information reduces the propensity to adopt through the formal seed system by 9%. Without access to information and input channels more typical for men's use, women may have reduced capacity to seize the opportunity of DTM (Badstue et al., 2020). With this in mind, any awareness-raising on the benefits of DTM varieties should target both women and men, addressing their varying gender roles, using tailor-made messaging and different formal and informal seed system communication channels. For example, to reach more women seed delivery interventions could use of more traditional domains for women, such as those linked to health and nutrition, and could promote information provision by women to women (Kramer and Trachtman, 2023).

Financial constraints directly influence the economic access to and affordability of DTM varieties. Indirectly, control over the benefits of using DTM seed also affects economic access and affordability. We have seen that both men and women face financial constraints, with men experiencing a higher impact, aligning with their role as providers. At the same time, women are less in control of the benefits of maize grain sales (Voss et al., 2021), limiting their options to mitigate climate and production risks. In addition, as a result of gendered norms, women tend to face mobility limitations hampering access to DTM varieties. Gender-related barriers to accessing DTM could be addressed through programs that respond to women's travel limitations and bring seed to alternative sales points closer to women's reach, accompanied by gender transformative engagement in communities to address structural barriers for women. Alternatively, free or subsidized seed distribution may be a pathway to increase access to resource-constrained men and women, as newly released DTM varieties are only available in the formal seed system.

Fisher et al. (2019) found that lower awareness of women can be explained by formal educational attainment, access to extension services, and characteristics of male and female social networks in Uganda. When controlling for these characteristics and others, such as capital, labor, and decision-making, the association between gender and awareness disappears (Fisher et al., 2019; Kramer and Trachtman, 2023; Voss et al., 2021). Many of these factors are mediated by socio-cultural norms surrounding gender. Our gender and risk perception analyses could call into question whether DTM - or, rather, DTM alone - is the most effective intervention for enhancing women's resilience to climate change and reducing gender disparities in climate change vulnerabilities. Climate services, training on improved agronomic practices (i.e., climate-smart agriculture) for crops that women have autonomous control over, and economic support for women's non-agricultural livelihood production could benefit women and help build resilience.

Furthermore, although contexts vary, it is possible that women-specific targeting of technological information and agricultural inputs could meet with male resistance as much as such targeting signifies women playing roles in agricultural production and income generation that have been typically men's. Similarly, we have seen more stringent gender norms in Dokolo, which seem less contested than in other districts. In Masindi, gender roles are changing, while at the same time, women's groups ranked the impact of risks related to social norms as the highest. Gender transformative approaches (GTA) can, therefore, be important because they engage with the complexity of gender to support women and men to act on the (context-specific) norms, attitudes, and broader structural constraints that limit their opportunities and outcomes (Farnworth et al., 2020).

4.2. Inseparability of risks in smallholder farming systems

Our explorative research found that agricultural decisions, and thus the uptake of DTM varieties, may be affected not only by production risks but also by health risks, risks related to social norms, and financial constraints. Our analysis suggests that these agricultural risks are inseparable. This non-separability of different risks in agriculture is caused by credit and insurance market imperfections that do not allow all risks to be separately or simultaneously insured and do not provide (sufficient) financial services during peak periods. Inseparability has

implications for agricultural risk management interventions and, subsequently, the uptake of (hybrid) DTM varieties. For example, without access to financial markets, households need buffers to 'self' insure against medical bills due to health-related risks. This leads to choices, amongst others, between investing in DTM seed or keeping a financial buffer for sickness. In addition, the risk of illness in the family poses a risk of losing the monetary investment in seed if good agronomic practices cannot be applied to manage crop production and climate risks.

Herberich and List (2012) show that the interplay of different risks (background risks) on production risks, such as uninsured labor risks, could increase the level of risk aversion of farmers. Therefore, it would be instrumental to empirically test whether health risks and financial constraints play a role when men and women make seed investment decisions in unpredictable weather conditions and whether a combination of risks increases the level of risk aversion. In addition, considering the gender differences in perceived risks in agriculture and in the socio-normative environment, it would be good to test whether different risk combinations affect men and women differently and lead to different (localized) agricultural investment choices.

The findings of such research may inform whether existing crop insurance could benefit from a broadening of scope. For example, adding a health component could promote agricultural investments for underserved smallholders, as agricultural insurance covers crop yield losses but does not insure against labor shortfalls and other agricultural risks (Kramer et al., 2022). In addition, as women may be more risk-averse than men in adopting DTM in the face of climate shocks (Teklewold et al., 2020), such research would inform whether gender-specific interventions are needed to address male and female risk aversion preferences.

4.3. Implications for integrated maize seed sector development

Our findings suggest that the use of home-saved seed may be, amongst others, a result of the inseparability of agricultural risks and gender roles and norms, deterring investment in DTM seed. The costs of shifting from home-saved (free) seed to the newer (hybrid) DTM varieties are high for smallholders facing poverty as risks are inseparable, and financial markets and risk management institutions do not function well for them. As a result of these market imperfections, endowment predicts input demand (Dillon and Barrett, 2017), creating unequal access to (hybrid) DTM varieties. This may partly explain why the formal seed system works, and agro-dealers are used to purchase seed, but only for more commercially oriented smallholders.

Our findings highlight that access to the formal seed system is in part context specific. Men in Iganga and Masindi more frequently mentioned access to the formal seed system, while in Dokolo, like women's groups in Dokolo and Iganga, mention informal seed sources more frequently.

To promote DTM as an inclusive and pro-poor idiosyncratic risk management solution, public variety development could also invest in open-pollinated drought-tolerant maize varieties that can be disseminated through formal and informal distribution channels. The informal system would primarily focus on OPVs, and the formal system would primarily involve hybrids. OPVs have a higher potential for diffusion through farmer-to-farmer networks and genetic improvement of home-saved seed. Particularly women would benefit as they access information and seed more often through informal channels. The investment in OPVs would facilitate more exchange between formal and informal systems, increasing access to improved varieties for men and women who do not use markets due to norms, risks in agriculture and financial constraints.

5. Conclusions

This study addressed which agricultural risks and constraints male and female smallholders in Uganda experience, how gender roles and norms may influence risk perceptions, and how these perceptions could pose additional barriers to adopting DTM varieties. We show that male and female smallholder farmers face several agricultural risks and constraints that go beyond the conventional research emphasis on production related risks such as climate change and crop management.

We find different risk perceptions between men's and women's groups conditioned by the socio-cultural normative environment, gender-prescribed roles, and gender differences in access to resources and agricultural decision-making. We note several gender trends, whereby women tend to mention climate and crop management risks more often and perceive a higher impact than men. Financial constraints are generally perceived higher by men, except for Masindi, where men's and women's groups rate them similarly. At the same time, we note variations across districts in the perceived impact of health risks, price risks, and social norms. Our gender analysis highlighted more traditional gender roles in Dokolo with more stringent social norms, while gender power over maize cultivation is more contested in Iganga, and gender roles seem to be shifting in Masindi. This comes back in the risk and concern ranking, where risks related to social norms appear in the top-five ranked concerns, with varying impacts amongst men and women in different districts. Overall, the risk and concern ranking shows more similarities between men's and women's responses in Dokolo than in Iganga and Masindi.

Generally, women have fewer resources available to address different risks in agriculture. To reach and benefit more women with DTM varieties, we draw attention to access to information, bringing seed closer (potentially subsidized) and gender transformative interventions that address gender norms.

In light of the inseparability of risks in agriculture, we suggest further empirical research to study the interplay between different risks in agricultural investments and risk aversion. If institutional risk management options were accessible, smallholders could gain from comprehensive insurance covering multiple risks in agriculture in support of the uptake of DTM technologies in the formal seed system.

Lastly, we observe that the seed sector in Uganda firmly relies on the formal seed system for disseminating hybrid DTM varieties. However, the inseparability of agricultural risk and prevailing gender norms may contribute to the high prevalence of home-saved seed. Therefore, smallholders would benefit from investments in public variety development of open-pollinated DTM varieties. OPVs would facilitate the dissemination of these varieties and information about them through the formal and informal seed systems. This approach provides more opportunities to tailor interventions to the specific needs of male and female smallholders.

CRediT authorship contribution statement

Astrid Mastenbroek: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Tatiana Gumucio:** Conceptualization, Formal analysis, Methodology, Validation, Writing – original draft, Writing – review & editing. **Josephine Nakanwagi:** Data curation, Formal analysis, Investigation, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgement

This work was produced as part of the Netherlands Organization for Scientific Research (NWO) and the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) in East Africa. CCAFS receives generous financial support from the CGIAR Trust Fund and CGIAR Donors through bilateral funding agreements. For details please visit https://ccafs.cgiar.org/donors. The views expressed in this document cannot be taken to reflect the official opinions of these organizations. The authors would like to thank the men and women in the villages, their respective organizations and CCAFS for their support of this work. The authors would like to thank the two anonymous reviewers, Erwin Bulte, Robert Sparrow and Kadi Warner for their valuable comments to improve the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.agsy.2024.103912.

References

Badstue, L.B., Kantor, P., Prain, G., Ashby, J., 2014. Innovation and Development Through Transformation of Gender Norms in Agriculture and Natural Resource Management: A concept note for GENNOVATE.

Badstue, L., Elias, M., Kommerell, V., Petesch, P., Prain, G., Pyburn, R., Umantseva, A., 2020. Making room for manoeuvre: addressing gender norms to strengthen the enabling environment for agricultural innovation. Dev. Pract. 30, 541–547. https://doi.org/10.1080/09614524.2020.1757624.

Barrett, C., Smith, K., Box, P., 2001. Not necessarily in the same boat: heterogeneous risk assessment among east African pastoralists. J. Dev. Stud. 37, 1–30. https://doi.org/10.1080/00220380412331322101.

Boucher, S.R., Carter, M.R., Flatnes, J.E., Lybbert, T.J., Malacarne, J.G., Marenya, P., Paul, L.A., 2021. Bundling stress tolerant seeds and insurance for more resilient and productive small-scale agriciculture (No. 29234), Paper Knowledge. In: Toward a Media History of Documents, NBER Working Paper.

Browne, S., Glaeser, L., 2010. Livelihood Mapping and Zoning Excercise: Uganda. A special report by FEWS NET, pp. 1–58. Retrieved on February 8, 2014 from: https://fews.net/sites/default/files/documents/reports/UG_zonedescriptions_en.pdf.

Carr, E.R., Thompson, M.C., 2014. Gender and climate change adaptation in agrarian settings: current thinking, new directions, and research Frontiers. Geogr. Compass 8, 182–197. https://doi.org/10.1111/gec3.12121.

Chivasa, W., Worku, M., Teklewold, A., Setimela, P., Gethi, J., Magorokosho, C., Davis, N.J., Prasanna, B.M., 2022. Maize varietal replacement in eastern and southern Africa: bottlenecks, drivers and strategies for improvement. Glob. Food Sec. 32, 100589 https://doi.org/10.1016/j.gfs.2021.100589.

Cullen, A.C., Anderson, C.L., Biscaye, P., Reynolds, T.W., 2018. Variability in cross-domain risk perception among smallholder farmers in Mali by gender and other demographic and attitudinal characteristics. Risk Anal. 38, 1361–1377. https://doi.org/10.1111/risa.12976.

de Janvry, A., Sadoulet, E., 2020. Using agriculture for development: supply- and demand-side approaches. World Dev. 133, 105003 https://doi.org/10.1016/j.worlddev.2020.105003.

de Janvry, A., Fafchamps, M., Sadoulet, E., 1991. Peasant household behaviour with missing markets some paradoxes explained. Econ. J. 101, 1400–1417.

Dillon, B., Barrett, C.B., 2017. Agricultural factor markets in sub-Saharan Africa: an updated view with formal tests for market failure. Food Policy 67, 64–77. https://doi.org/10.1016/j.foodpol.2016.09.015.

Duong, T.T., Brewer, T., Luck, J., Zander, K., 2019. A global review of Farmers' perceptions of agricultural risks and risk management strategies. Agriculture 9, 10. https://doi.org/10.3390/agriculture9010010.

Fagereng, A., Guiso, L., Pistaferri, L., 2016. Back to Background Risk?, Discussion Papers, No. 834, Statistics Norway, Research Department Oslo.

Farnworth, C.R., Badstue, L., Williams, G.J., Tegbaru, A., Gaya, H.I.M., 2020. Unequal partners: associations between power, agency and benefits among women and men maize farmers in Nigeria. Gend. Technol. Dev. 24, 271–296. https://doi.org/10.1080/09718524.2020.1794607.

Fisher, M., Carr, E.R., 2015. The influence of gendered roles and responsibilities on the adoption of technologies that mitigate drought risk: the case of drought-tolerant maize seed in eastern Uganda. Glob. Environ. Chang. 35, 82–92. https://doi.org/10.1016/j.gloenvcha.2015.08.009.

Fisher, M., Abate, T., Lunduka, R.W., Asnake, W., Alemayehu, Y., Madulu, R.B., 2015. Drought tolerant maize for farmer adaptation to drought in sub-Saharan Africa: determinants of adoption in eastern and southern Africa. Clim. Change 133, 283–299. https://doi.org/10.1007/s10584-015-1459-2.

Fisher, M., Habte, E., Ekere, W., Abate, T., Lewin, P.A., 2019. Reducing gender gaps in the awarenss and update of drought-tolerant maize in Uganda: the role of education, extension services and social networks. AgriGender J. Gender Agric. Food Secur. 4, 38–50. https://doi.org/10.19268/JGAFS-412019-4.

Hansen, J., Hellin, J., Rosenstock, T., Fisher, E., Cairns, J., Stirling, C., Lamanna, C., van Etten, J., Rose, A., Campbell, B., 2019. Climate risk management and rural poverty reduction. Agr. Syst. 172, 28–46. https://doi.org/10.1016/j.agsy.2018.01.019.

Hansen, J., List, G., Downs, S., Carr, E.R., Diro, R., Baethgen, W., Kruczkiewicz, A., Braun, M., Furlow, J., Walsh, K., Magima, N., 2022. Impact pathways from climate services to SDG2 ("zero hunger"): a synthesis of evidence. Clim. Risk Manag. 35, 100399 https://doi.org/10.1016/j.crm.2022.100399.

Hardaker, J.B., Lien, G., Anderson, J.R., Huirne, R.B.M., 2015. Coping with risk in agriculture, 3rd editio. Ed, coping with risk in agriculture. CABI, Wallingford. https://doi.org/10.1079/9780851998312.0000.

Harwood, J., Richard, H., Coble, K., Perry, J., Somwaru, A., 1999. Managing Risk in Farming: Concepts, Research, and Analysis. (No. 774), Agricultural Economic Report, Agricultural Economic Report. Washington, DC.

Herberich, D.H., List, J.A., 2012. Digging into background risk: experiments with farmers and students. Am. J. Agric. Econ. 94, 457–463. https://doi.org/10.1093/ajae/aar070.

Hoogendoorn, J.C., Audet-Bélanger, G., Böber, C., Donnet, M.L., Lweya, K.B., Malik, R. K., Gildemacher, P.R., 2018. Maize seed systems in different agro-ecosystems; what works and what does not work for smallholder farmers. Food Secur. 10, 1089–1103. https://doi.org/10.1007/s12571-018-0825-0.

Huet, E.K., Adam, M., Giller, K.E., Descheemaeker, K., 2020. Diversity in perception and management of farming risks in southern Mali. Agr. Syst. 184, 102905 https://doi.org/10.1016/j.agsy.2020.102905.

Kabeer, N., 1999. Resources, agency, achievements: reflections on the measurement of women's empowerment. Dev. Change 30, 435–464. https://doi.org/10.1111/1467-7660.00125.

Karlan, D., Osei, R., Osei-akoto, I., Udry, C., 2014. Agricultural Decions after relaxing credit and risk constraints. Q. J. Econ. 129, 597–652. https://doi.org/10.1093/qje/qju002.Advance.

Kassie, M., Abro, Z., Wossen, T., Ledermann, T., Diiro, G., Ballo, S., Belayhun, L., 2020. Integrated health interventions for improved livelihoods: a case study in Ethiopia. Sustainability 12, 2284. https://doi.org/10.3390/su12062284.

Key, N., Sadoulet, E., De Janvry, A., 2000. Transactions costs and agricultural household supply response. Am. J. Agric. Econ. 82, 245–259. https://doi.org/10.1111/0002-9092.00022.

Komarek, A.M., De Pinto, A., Smith, V.H., 2020. A review of types of risks in agriculture: what we know and what we need to know. Agr. Syst. 178, 102738 https://doi.org/10.1016/j.agsy.2019.102738.

Kramer, B., Trachtman, C., 2023. Gender dynamics in seed systems: an integrative review of seed promotion interventions in Africa. Food Secur. https://doi.org/10.1007/s12571-023-01403-2.

Kramer, B., Hazell, P., Alderman, H., Ceballos, F., Kumar, N., Timu, A.G., 2022. Is agricultural insurance fulfilling its promise for the developing world? A review of recent evidence. Annu. Rev. Resour. Econ. 14, 291–311. https://doi.org/10.1146/annurev-resource-111220-014147.

Mastenbroek, A., Sirutyte, I., Sparrow, R., 2021. Information barriers to adoption of agricultural technologies: willingness to pay for certified seed of an open pollinated maize variety in northern Uganda. J. Agric. Econ. 72, 180–201. https://doi.org/10.1111/1477-9552.12395.

Meinzen-Dick, R., Johnson, N., Quisumbing, A., Njuki, J., Behrman, J., Rubin, D., Peterman, A., Waithanji, E., 2011. Gender, Assets. In: And Agricultural Development Programs (No. 99), CAPRi Working Paepers, CAPRi Working Papers. Washington, DC. https://doi.org/10.2499/CAPRiWP99.

Murray-Prior, R., 1998. Modelling farmer behaviour: a personal construct theory interpretation of hierarchical decision models. Agr. Syst. 57, 541–556. https://doi.org/10.1016/S0308-521X(98)00008-0.

Mwongera, C., Shikuku, K.M., Twyman, J., Läderach, P., Ampaire, E., Van Asten, P., Twomlow, S., Winowiecki, L.A., 2017. Climate smart agriculture rapid appraisal (CSA-RA): A tool for prioritizing context-specific climate smart agriculture technologies. Agr. Syst. 151, 192–203. https://doi.org/10.1016/j.agsy.2016.05.009.

Osiemo, J., Ruben, R., Girvetz, E., 2021. Farmer perceptions of agricultural risks; which risk attributes matter most for men and women. Sustain 13, 1–26. https://doi.org/10.3390/su132312978.

PARM, 2014. Terms of reference for agricultural risk assessment studies (No. 1), Parm working paper. Rome : PARM / IFAD. Retrieved on January 8, 2023 from:

PARM, 2018. Agricultural Risk Assessment Study in Liberia (by CEIGRAM). Rome : PARM/IFAD. Retrieved on January 8, 2023 from.

Prasanna, B.M., Cairns, J.E., Zaidi, P.H., Beyene, Y., Makumbi, D., Gowda, M., Magorokosho, C., Zaman-Allah, M., Olsen, M., Das, A., Worku, M., Gethi, J., Vivek, B.S., Nair, S.K., Rashid, Z., Vinayan, M.T., Issa, A.R.B., San Vicente, F., Dhliwayo, T., Zhang, X., 2021. Beat the stress: breeding for climate resilience in maize for the tropical rainfed environments. Theor. Appl. Genet. 134, 1729–1752. https://doi.org/10.1007/s00122-021-03773-7.

Quinn, C.H., Huby, M., Kiwasila, H., Lovett, J.C., 2003. Local perceptions of risk to livelihood in semi-arid Tanzania. J. Environ. Manage. 68, 111–119. https://doi.org/10.1016/S0301-4797(03)00013-6.

Rengalakshmi, R., Manjula, M., Deveraj, M., 2018. Making climate information gender sensitive: lessons from Tamil Nadu. Econ. Pol. Wkly 53, 87–95.

Rohrmann, B., 2008. Risk perception, risk attitude, risk communication, risk management: a conceptual appraisal. In: 15th Internaional Emerg. Manag. Soc. Annu. Conf. June, 1–10.

Rutsaert, P., Donovan, J., 2020. Sticking with the old seed: input value chains and the challenges to deliver genetic gains to smallholder maize farmers. Outlook Agric. 49, 39–49. https://doi.org/10.1177/0030727019900520.

Siegel, P.B., Alwang, J., 1999. An Asset-Based Approach to Social Risk Managment: A Conceptual Framework (No. 9926), SP Discussion Paper. Washington, DC.

Simtowe, F., Amondo, E., Marenya, P., Rahut, D., Sonder, K., Erenstein, O., 2019. Impacts of drought-tolerant maize varieties on productivity, risk, and resource use: evidence from Uganda. Land Use Policy 88, 104091. https://doi.org/10.1016/j.landusepol.2019.104091.

Smith, K., Barrett, C.B., Box, P.W., 2000. Participatory risk mapping for targeting research and assistance: with an example from east African pastoralists. World Dev. 28, 1945–1959. https://doi.org/10.1016/S0305-750X(00)00053-X.

Takahashi, K., Muraoka, R., Otsuka, K., 2020. Technology adoption, impact, and extension in developing countries' agriculture: a review of the recent literature. Agric. Econ. 51, 31–45. https://doi.org/10.1111/agec.12539.

Teklewold, H., Adam, R.I., Marenya, P., 2020. What explains the gender differences in the adoption of multiple maize varieties? Empirical evidence from Uganda and Tanzania. World Dev. Perspect. 18, 100206 https://doi.org/10.1016/j.wdp.2020.100206.

Timu, A.G., Kramer, B., 2021. Gender-inclusive, −responsive and-transformative agricultural insurance: A literature review (No. 417). In: CCAFS working paper. Wageningen, the Netherlands.

UBOS, 2017. Uganda Bureau of Statistics 2017 Statistical Abstract. Uganda Bureau of Statistics, Kampala.

UBOS, 2020. Uganda Annual Agricltural Survey 2018. Uganda Bureau of Statistics, Kampala, Uganda.

Vakis, R., Sadoulet, E., de Janvry, A., Cafiero, C., 2004. Testing for Separability in Household Models with Heterogeneous Behavior: A Mixture Model Approach (No. 990), CUDARE Working Papers. Berkeley.

van Winsen, F., de Mey, Y., Lauwers, L., Van Passel, S., Vancauteren, M., Wauters, E., 2013. Cognitive mapping: a method to elucidate and present farmers' risk perception. Agr. Syst. 122, 42–52. https://doi.org/10.1016/j.agsy.2013.08.003.

Voss, R.C., Donovan, J., Rutsaert, P., Cairns, J.E., 2021. Gender inclusivity through maize breeding in Africa: a review of the issues and options for future engagement. Outlook Agric. 50, 392–405. https://doi.org/10.1177/00307270211058208.

Wossen, T., Abdoulaye, T., Alene, A., Feleke, S., Menkir, A., Manyong, V., 2017. Measuring the impacts of adaptation strategies to drought stress: the case of drought tolerant maize varieties. J. Environ. Manage. 203, 106–113. https://doi.org/10.1016/j.jenvman.2017.06.058.

Zúñiga, F., Jaime, M., Salazar, C., 2021. Crop farming adaptation to droughts in small-scale dryland agriculture in Chile. Water Resour. Econ. 34, 100176 https://doi.org/10.1016/j.wre.2021.100176.