





## Article

# The Role of Gender and Institutional Dynamics in Adapting Seed Systems to Climate Change: Case Studies from Kenya, Tanzania and Uganda

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**Abstract:** We explore how seed systems enhance access to seeds, and information for climate-change adaptation in farming communities in Kenya, Tanzania and Uganda, as well as how gender-driven roles and institutional dynamics influence the process. Men and women farmers equally experience climate-change related effects, including drought, short rainy seasons and increased pest and disease incidence. Our study relies on exploratory data analysis of 1001 households surveyed in four sites in 2016. Farmers surveyed preferred early-maturing, heat-tolerant, high-yielding, and pest- and disease-resistant varieties, all important climate-adaptive traits. Seed systems of the focus crops studied are largely informal—overall, 68% women and 62% men use their own seed, indicating women's higher reliance on 'informal' seed and information sources. Only 21% of respondents reported interacting with seed experts who are affiliated with formal organizations. Both formal and informal organizations play a key role in providing access to climate-adapted seed/information, with access for men and women varying across the countries studied. There is a need to support further development of those connections, building on existing social networks. We conclude that inclusive and gender-responsive context- and country-specific seed interventions will ensure equitable outcomes, increase women's empowerment and strengthen both formal and informal seed systems for more effective climate-change adaptation.

**Keywords:** adaptation; climate change; gender; institutions; seed systems



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## 1. Introduction

Smallholder agricultural households, particularly in sub-Saharan Africa, are one of the most vulnerable groups to climate change, which adversely affects agricultural production—their main source of livelihood [1]. Estimates indicate that, by 2050, climate change might reduce global agricultural productivity by 17%, increasing producers' vulnerability to food insecurity [2]. Climate-change related risks for smallholders are associated with their limited adaptive capacity and dependence on rain-fed agriculture. Some of the climate change-induced environmental changes that impact crop production include heat stress,

drought stress, shorter cropping seasons and unpredictable rainfall patterns [3–5]. Farmers can adapt to climate change by switching to more resilient crops, such as millet, sorghum and cassava, or to more resilient varieties with desirable traits [6]. Other options for adapting to climate change include accessing new technologies related to seeds, fertilizers, pesticides and irrigation [7]. Examples of seed system interventions that increase the resilience of smallholder agricultural production systems include developing adapted crop varieties, and ensuring access to seed of a diversity of crops and crop varieties that are adaptable to different environments [8]. The dissemination of climate resilient seeds at the right time and right price could further be promoted through improved transportation networks and investments in seed bulking and storage facilities, improvement of coverage and quality of extension services, better access to subsidized inputs and improved supply chain networks [9]. Access to new seeds and technologies, however, can be difficult, particularly for resource-poor farmers [10].

Seeds systems can be categorized as formal, informal and intermediary. This characterization is based on different factors, which include “... the domains in which they operate (public, private, informal, formal, mixed); the type of crops involved (food crops, cash crops); the type of varieties used (landrace, improved, exotic, hybrid); the type of seed quality assurance mechanisms operational (informal, Quality Declared Seed, certified), and; the seed dissemination mechanisms active (local exchange, agro-input distribution schemes, agro-dealers)” [11]. These systems serve diverse groups of women and men with different needs and preferences. Therefore, there is a need for sustainable and efficient seed systems that provide seed with desirable qualities, at the right time, place and in the right quantity [12].

In sub-Saharan Africa, smallholder farmers, in particular women, have limited production capacity for most crops and tend to be involved in informal, subsistence-oriented crop production [13]. They are limited in their access to good quality seed, lack mobility, have limited decision-making power and limited participation in formal seed systems [14–16], which translates into low productivity and low income. Subsistence agriculture is also characterized by inefficiencies in terms of return to labor; wage is not an expression of marginal productivity, but of average productivity (for a more in-depth discussion, see the literature [17–20]).

The roles of men and women in seed selection, adoption, seed production, management and use depend on the crop, norms, cultural/community values and other socio-economic and demographic factors [14]. These factors, diverging and shared interests may impact the livelihoods and wellbeing of the various seed value chain actors differently [21]. This calls for holistic and inclusive interventions at the individual level. Targeting the household or community as an entry point for seed systems interventions might overlook other actors. To ensure seed systems are gender-responsive and inclusive, the complexity of gender dynamics, constraints and challenges that shape or restrict decisions, choices and behavior of groups, communities and individuals all need to be identified and addressed [22]. Farming households organize themselves in different ways depending on various socioeconomic, cultural factors and the control and decision making dynamics. Issues related to who makes production decisions, such as what crop or crop variety to grow, on which plot, in what proportion, what seeds to source, when and how to sow, among other factors, might influence the outcomes [23]. The type of household—whether it is male-headed, or female-headed also impacts how the household organizes itself [14]. Men and women in male-headed households might have different preferences, particularly compared with women in female headed households [24]. Understanding gender dynamics is thus important for identifying direct users of interventions (who is considered responsible for the different tasks, making investments and doing the work), and for determining who might benefit or lose from them [25].

Due to their socially-constructed roles and responsibilities, women and men might experience climate-change impacts differently [26]. Understanding and incorporating gender dynamics is therefore vital for the development of effective climate-change interventions.

Furthermore, climate-change related effects now and in the future require concerted efforts to ensure food, nutrition and income security. Building resilient seed systems will contribute to these outcomes [27]. Access to, and use of, adaptable crops and climate-smart varieties that are better suited to the diverse environments is crucial for improving the resilience of seed systems [8]. However, gender-specific needs, preferences, challenges and opportunities are largely unknown or overlooked by the seed sector [14].

There are potential differences in seed and information networks used by men, women, youth and other social categories. Therefore, the type of information exchanged, and the knowledge gained might differ. Understanding the dynamics of gendered access and exchange of seed and related information regarding climate-change adaptation can inform gender-specific approaches and interventions that might be needed to improve access to, and foster, effective information exchange.

This article explores the role of gender in adapting seed systems to climate change in selected sites in East Africa, which is an area of research requiring a more detailed understanding that can inform the design and implementation of targeted seed interventions. The novelty of this paper is that it looks at the institutional dynamics of seed delivery taking cognizance of the importance both public and private entities in the coordination of the seed system and in the flow of information. The specific questions are: (1) What are the institutional channels through which women and men source/access seed and related information for climate-change adaptation? (2) Are there gender-based differences in choices of crops and varieties used to cope with climate change? Based on the research results, this article concludes by providing recommendations for research and practice. The paper contributes to the literature on seed systems and climate change adaptation by providing a cross-country comparison of gender differentiated and site-specific dynamics in seed and information access for climate change adaptation in three countries in East Africa. The sites have been the target of seed systems and climate change related interventions under the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS); thus, contributing to a global program on climate change adaptation. The article is organized as follows: Section 2 describes the conceptual framework and associated empirical literature on gender dynamics in seed and information access, use and climate-change adaptation. Section 3 outlines the methodology. In Section 4, we present results that compare information reported by women and men on climate-change perceptions, coping strategies, seed sources and institutional dynamics in seed access for the study sites. Section 5 discusses and interprets our findings. Section 6 presents the conclusion and recommendations on integrated seed systems interventions.

## 2. Conceptual Framework

### 2.1. Gender, Access and Choice

Gender defines men's and women's specific roles, status and expectations within households, communities, institutions and cultures [28]. The ability and opportunity to participate in formal or informal institutions within, and outside, one's community is often gendered and influences the capacity to adapt to change [10]. Gender dynamics are embedded in the social fabric of most communities and interact with choice, access, decision making, opportunities and challenges. For smallholder farming communities, seed and information access may depend on financial capital, social capital and other assets, which are often gendered. Moreover, women and men often have gender-specific needs, levels of trust and preferred channels of information dissemination [29].

Adaptation needs are likely to differ for individuals and groups depending on where they live, how they sustain their livelihoods, the roles they play in the household and communities and their ability to access climate-change related information. Socially determined differences in opportunities, responsibilities and decision-making power may influence the level of vulnerability and set of choices available to adapt to climate change. Without understanding these dynamics, which are often influenced by gender, there is a risk that the people with the greatest need for adaptation might be left out.

## 2.2. Gender Dimensions and Climate-Change Adaptation

The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment report indicates that Equatorial, Eastern and Southern parts of Africa have experienced significant temperature increases in the last 50 years, a phenomenon that is likely to continue in the next couple of decades [30]. Predictions indicate that by 2050 there will be a 2–4-degree Celsius increase in temperatures across Eastern and Southern Africa, coupled with increased rainfall variability and uneven cropping seasons. These climate-induced changes will amplify existing stresses on water availability and agricultural systems particularly for smallholder farmers (ibid). This is likely to exacerbate food insecurity, leading to increased migration and poverty, if no mitigation measures are implemented.

The poor and marginalized members of society who depend substantially on natural resources are most likely to be affected by climate change [31]. In Africa, small-scale, family-run farms are responsible for the production of up to 90% of the food in some sub-Saharan African countries [32]. Agriculture, a highly climate-sensitive sector, supports the livelihoods of over 50% of Africa's population; it contributes to about 15% of the continent's gross domestic product (GDP) and secures employment for more than two-thirds of the continent's labour force [33]. Smallholder farmers are disproportionately affected by climate change, as they have no capital base to employ in adapting to climate change or diversifying their sources of livelihood. Climate change also affects men and women differently given their different roles and responsibilities in agriculture and food production at the household and community level [34]. Women are more exposed and vulnerable to climate change because they are often poorer, receive less education, and are minimally involved in the political and household decision-making processes that affect their lives. Cultural norms related to gender sometimes limit the ability of women to make decisions regarding strategies they can use for climate-change adaptation (ibid).

Access to information related to climate, weather or available technologies can help improve adaptation strategies. This underscores the important role of making climate-related information available to farmers. Adaptation requires that farmers first notice that the climate has changed, and then identify useful adaptation strategies and implement them [35]. The lack of access to information can act as a barrier to climate-change adaptation. Moreover, gender disparities in accessing information can further exacerbate women's capacity to adapt to climate change [10]. The use of information and communication technologies (ICT) is one of the avenues for disseminating climate-change related information. McGuire [36] noted that the majority (86%) of farmers in both rural and urban areas in Africa possess or can access mobile phones where two-way feedback systems on climate-change responsive innovations can be shared. Information on climate-smart agricultural practices, such as high yielding, stress-tolerant crop varieties and agroforestry [37] can be disseminated through seed fairs, local markets and farmer organizations. However, mobility restrictions, isolation and low participation in promotion activities, preference of men over women by extension agents and the production and reproduction responsibilities of women restrict their access to information [10,38,39].

## 2.3. Gender and Institutional Dynamics in Seed and Information Access

Institutions (which include market, state and local-level customary institutions) play an important role in seed systems and influence seed access, seed use and information access. They can be defined as the complexes of norms and behaviors that humans use to organize structured relations [40]. They can exist as both formal and informal structures across a spectrum of public, private and civic sectors in the form of memberships [41]. Institutions also encompass norms and rules within which people and organizations operate.

Smallholder women and men farmers use different social networks to access seed, seed-related information and general agriculture-related information. Informal systems, also known as 'local' or 'farmers' seed system(s) predominate as the sources of seed [42–45]. Compared to men, women tend to form stronger family ties and share learning experiences

within social networks in their communities [44]. Social networks that provide agriculture-related information for women are largely composed of women, which might limit their access to and learning about new agricultural technologies compared to the more formal connections that are available to their male counterparts [6,37]. Male farmers tend to subscribe to social networks that are predominantly male [46] from which they acquire first-hand updated agricultural information.

Local institutions have shaped how rural residents respond to environmental challenges. They are also the mechanisms that will translate the impact of future external interventions to facilitate adaptation to climate change. Given that adaptation to climate change is localized, it is critically important to better understand the role of institutions in shaping adaptation and improving capacities of the most vulnerable social groups, such as women [47]. Institutions not only shape the impact of climate change on rural households, but also shape the way communities and individual households respond to climate change (ibid).

Effective climate-change adaptation may depend on the types of institutions individuals and communities have access to and use. They can create frameworks within which specific adaptation practices and social networks can be harnessed to access resources or information. Institutions could also impede access to and have control over resources and the adoption and use of technologies, such as climate-smart agricultural practices. The outcome(s) of (no) access and use often have a gender dimension [37]. Actors are embedded in social networks through which information is shared and local institutions may also mediate external interventions and reinforce or undermine adaptation strategies. An actor's ability to access these institutions therefore will determine their adaptation.

Information on quality seeds adapted to farmers' needs and timely access to these seeds is of utmost importance for climate-change adaptation. Quality seeds, as well as improved or hybrid varieties, are normally produced by and accessed through formal sources and are geared to commercial large-scale production. Therefore, they are usually costly and not accessible to resource-constrained (women) farmers [48].

The literature highlights gender-specific differential dynamics in seed and information access, use, choice (in general) and climate change adaptation (in particular). There is limited literature on comparative studies in East African countries that assesses the institutional channels that men and women farmers use to access seed and information about seeds in the region. The specific hypothesis is that men farmers in Kenya, Tanzania and Uganda have access to more channels and are more likely to use formal institutional channels than women. In addition, there are gaps in gender-differentiated information on the crops and varieties being promoted/used to cope with effects related to climate change. Here, the hypothesis is that men and women have different crops and crop varieties that they use to cope with climate change effects, and this could be due to the differences in their abilities to access seeds of certain crops and varieties. The lack of exploratory studies on these aspects hinders the design of effective targeted interventions and frameworks at the national and regional levels. Our research builds and expands on the literature by assessing these factors and interlinkages for men and women in different contextual settings in Kenya, Tanzania and Uganda. Based on the results, we make context-specific recommendations for women and men farmers.

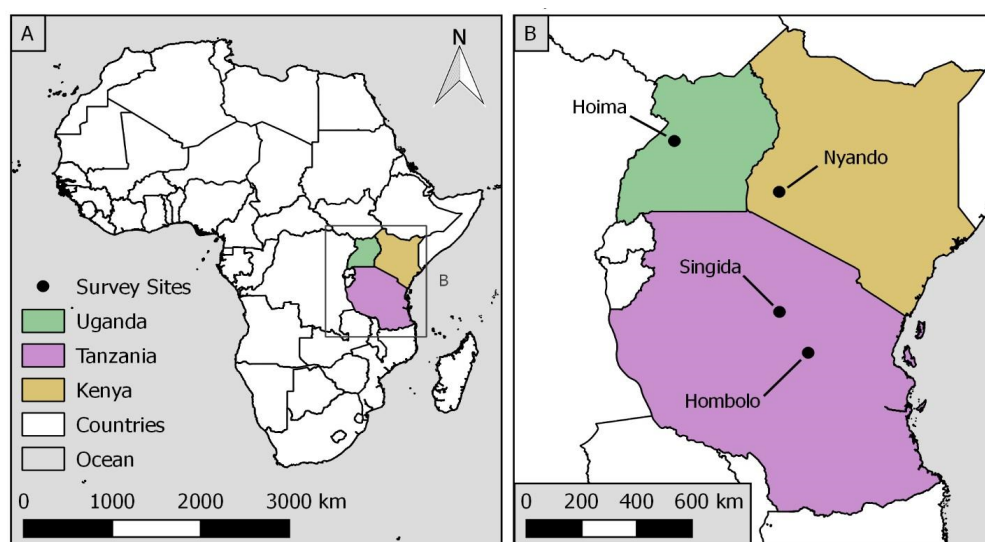
### 3. Methodology

#### 3.1. Study Area

The study was conducted in select sites in Kenya, Tanzania and Uganda. The sites were selected to be representative of the agro-ecological systems in the region ranging from semi-humid to semi-arid. The four sites: Nyando in Kenya, Hombolo and Singida in Tanzania, and Hoima District in Uganda (Figure 1) were selected from a subset of the target countries of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) in East Africa. The sites have a high degree of poverty and vulnerability to climate change, as well as complementary climatic, social and institutional contexts



worth investigating. In these sites, agriculture is the main activity for food security and livelihoods, and smallholder farmers in the sampled communities practice mixed farming (Table 1). The sites typically consist of smallholder farmers facing challenges that are related to climate-change adaptation, such as access to climate-adapted seeds, access to information and low adaptive capacity to address climate change risks. A mixed methods approach that involved a household survey and focus group discussions (FGDs) was used to collect data from these sites.



**Figure 1.** Selected study areas in East Africa (A) and survey sites in Kenya, Tanzania, and Uganda (B).

**Table 1.** Geographical and farming characteristics of the study sites.

	Lower Nyando—Kenya	Upper Nyando—Kenya	Hombolo—Tanzania	Singida—Tanzania	Hoima—Uganda
Farming system	Mixed subsistence	Mixed subsistence to commercial	Mixed subsistence	Mixed subsistence	Mixed subsistence
Agroecology	Semi-arid—Sub humid	Sub-humid	Semi-arid	Semi-arid—Sub humid	Sub-humid
Average rainfall (mm)	800	1220	400	600	1200
Temperature (°C)	18–34	12–30	12–35	12–30	12–32
Altitude (masl)	1100–1300	1200–1400	1100	1500	1120

Source: Authors' compilations.

### 3.2. Data and Methods

A preliminary focus group discussion with 12–20 farmers in each site was conducted to understand the community dynamics related to farmers' perceptions on climate change, the level of crop diversity in the community; the institutions and experts that interact with the communities for both seeds and information; and the strength of community relationships with extension services, research institutions, non-governmental organizations (NGOs) and different public and private institutions, including farmer organizations. Household data were then collected between July and October 2016. A snowball sampling technique where researchers interviewed two nodal farmers—a male and a female identified using focus group discussions (FGDs) as having influence or leadership roles in agricultural issues in their villages was used. As part of the survey, farmers were asked to identify who they had received seeds from or given seeds to, in order to establish the next cohort of farmers to interview. Participants were also asked to name where they sourced the seed (e.g., local markets, research and extension services, private companies, or other farmers). Enumerators then surveyed farmers named by the first two nodal farmers, and this sampling continued iteratively until interviewed farmers began mentioning the same names, or until no remaining farmers stated sourcing seed from others in the village. At the end of this process, a total of 1001 households were interviewed—365 from (Lower and Upper) Nyando in Kenya, 334 from Hombolo and Singida in Tanzania and 302 from Hoima

district in Uganda. The collected data included various socio-economic and demographic variables, such as age, sex, level of education, asset ownership; information on climate-change perception and coping mechanisms; institutions that operate and disseminate seed, related technologies and information, including research, extension services, local and international NGOs, farmers' organizations, private sector companies and CGIAR Centers. Follow up FGDs were conducted in each of the study sites to corroborate the information collected in the survey.

Data analyses were conducted in MS Excel 365 (Microsoft, Redmond, WA, USA) and Stata v14 (StataCorp, College Station, TX, USA) using descriptive statistics by site and sex of the respondent. This was followed by a comprehensive exploratory analysis of institutions, identification of gender dynamics related to access and exchange of seeds, as well as the interactions between institutions and farmers in the dissemination and exchange of seeds and related information. Data are presented as frequencies, percentages and means. Given the differences in sample sizes, crops and crop varieties grown in each of the three countries, sex disaggregated analyses are done separately for each country. Statistical tests that were conducted include Pearson's chi-squared tests used to determine whether there is a significant association between categorical variables (i.e., whether the variables are independent or related), independent samples *t*-tests to assess if there were significant differences in the mean proportion of men and women reporting specific aspects in each of the three target countries and pairwise comparisons using Tukey HSD to test for significant differences between a pair of group means.

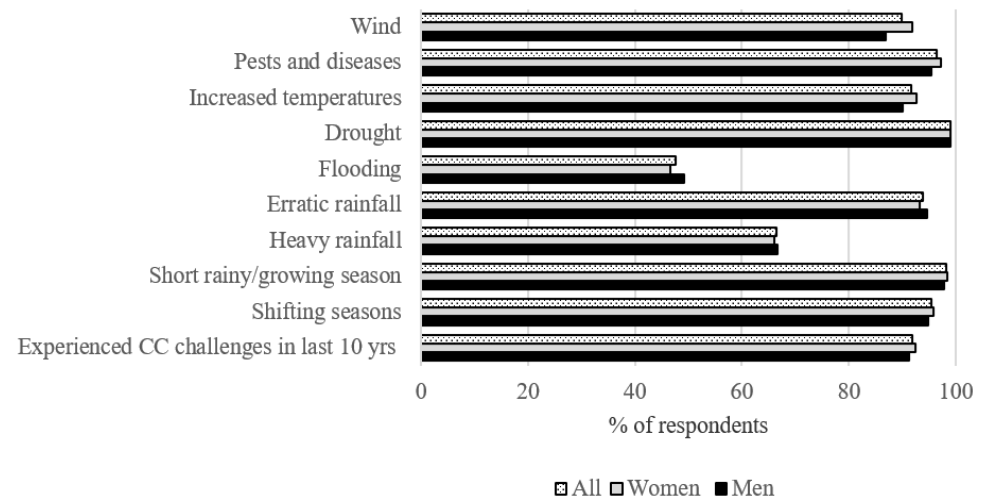
## 4. Results

### 4.1. Respondents' Demographic and Socio-Economic Characteristics

The demographic and socio-economic characteristics of our survey respondents are summarised in Appendix A Table A1. More than 88% of respondents were middle-aged (>31 yrs) and older adults (>45 yrs). Only around 10% of respondents were aged under 30, which perhaps indicates that this demographic was not included in the sampling for the study or that they are not actively involved in farming or they have migrated out of the communities. The majority of respondents had completed primary education or higher. Just over three quarters were married; those widowed were mostly women (20.1%). Almost all were engaged in crop farming. In terms of assets providing access to information (TV, radio and mobile phones), almost all respondents indicated that they had access to at least one asset; however, overall, more men had access compared to women (91.8% vs. 86.1%, respectively;  $p = 0.006$ ). Even when the analysis is done by information asset, more men reported having access compared to women: TV (15.3% vs. 10.7%, respectively); radio (75.3% vs. 63.8%, respectively) and mobile phone (82.9% vs. 79.3%, respectively). There was a significant association between sex and access to radio and TV ( $p < 0.05$ ) but the association for mobile phones is not significant.

### 4.2. Climate-Change Perceptions and Coping Strategies

More than 85% of respondents in the three countries indicated that they have experienced the effects of climate change, which has affected their productivity (Figure 2). Erratic rainfall, shorter growing seasons and shifting seasons were most notably felt by both men and women in all the sites. Other observations included increased pests and diseases, and increased temperatures. This means that farmers require more drought-tolerant, shorter-season varieties to cope with the effects of climate change.



**Figure 2.** Farmers' perceived climate-change related challenges experienced in the last 10 years.

#### 4.3. Crops and Varieties Used to Cope with Climate-Change Related Effects

As a follow-up question to the climate-related effects they had experienced in the past 10 years, respondents were asked if they used specific varieties to cope with climate change. Thirty-four percent of the total respondents ( $n = 388$ ; 51% women) indicated that they used specific varieties of certain crops to cope with climate change. Appendix A Table A2a–c show sex-disaggregated information on varieties used to cope by crop and by county. A total of 55 varieties were mentioned—of these 23 were beans, 22 sorghum, 7 finger millet and 3 forage legumes. Farmers in Kenya mentioned more varieties ( $n = 30$ ) compared to those in Tanzania (14) and Uganda (13). In Uganda, women mentioned more varieties than the men (13 vs. 5). When it comes to the specific crop varieties, women in Tanzania and Uganda mentioned more bean varieties than men—none of the men in Tanzania mentioned bean varieties, whereas women in Uganda mentioned a total of eight varieties, which accounts for twice as many as those mentioned by the men. Similarly, in Tanzania, only women mentioned cowpea, a legume crop. These differences could be explained by men and women being responsible for specific crops or having access to different crop varieties and hence are aware of the specific varieties, which are adapted to localized changing climatic conditions.

Data obtained from FGDs with farmers indicate that these varieties are preferred for climate-change adaptation mainly because they are early maturing and can withstand periods of drought and erratic rainfall. For instance, local sorghum landrace *Ochuti* was rated high for drought tolerance and yield stability compared to the improved varieties *Serena* and *Seredo* by farmers in Nyando, Kenya. Bean varieties, which were also mentioned by the study participants and have desirable characteristics included: *Mwezi moja*, which is reported to perform well in dry areas, mature early and is tolerant to drought; *KAT B9*, which is tolerant to heat; *Mwezi mbili*, which has large grains and is resistant to several diseases; and *Wairimu*, which matures early, heat tolerant and useful for intercropping. Participants in Tanzania prefer *Marcia* sorghum variety, which is high yielding and early maturing.

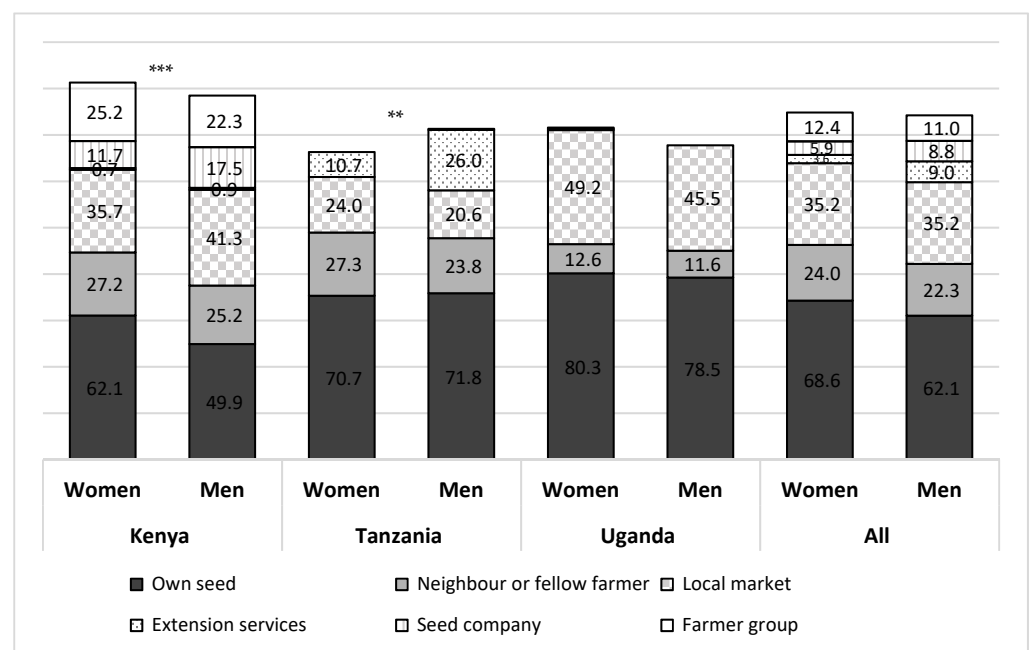
There are significant differences in the proportion of men and women who mentioned certain varieties, but the proportion is relatively low e.g., *Seed engufu* local bean variety (11.8% vs. 18.3%, respectively) and *Pato* improved sorghum variety (4.8% vs. 0.5%, respectively) (refer to Appendix A Table A2). Furthermore, women's and men's differing preferences for varieties might depend on the portfolio of varieties available where they source their seed.



#### 4.4. Seed Sources (by Sex and Country)

Kinship ties and local markets still serve as the most important sources of seed that are appropriate for climate-related challenges (Figure 3). Seed systems for all the focus crops are largely informal (own farm, neighbor/fellow farmer). A greater proportion of women than men rely more on informal sources with less access to formal sources, such as seed companies. In Kenya, only 11.7% of women indicated that they access seed through seed companies compared to 17.5% of men; whilst overall, 5.9% of women compared to 8.8% of men indicated the same—the differences are very small and proportions are low for both men and women.

Farmer groups also play a critical role in acting as an intermediary for seeds and information, and they are more accessible to women. A more in-depth assessment of the types of groups that farmers belong to and the climate- and seed-related information or seeds they obtain is presented in more detail in the next section (Institutional dynamics in access to information and seed). Extension services and research organizations play a critical role in providing seed to farmers, especially for the dissemination of new varieties or testing newly-bred varieties. Overall, more men reported extension as a seed source compared to women, however, this was a small proportion overall (9% men vs. 3.6% women;  $p = 0.000$ ). There are differences by country—in Kenya and Uganda, a very small percentage of men and women indicated they used extension services (0.9% vs. 0.7%, respectively) in Kenya and (0.6% vs. 0.0%, respectively) in Uganda; whereas, in Tanzania, a higher proportion of both men and women compared to the other two countries (26% vs. 10%, respectively) indicated extension services as seed sources. This reiterates the need to improve capacity at the local level to ensure farmers have the necessary support from extension services, as this can increase productivity and implementation of climate-change adaptation measures.



**Figure 3.** Seed sources, by country and sex (% of respondents). \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$  show significant association between respondent sex and seed source for that country using chi square tests.

Conducting the analysis according to the type of crop indicates that, irrespective of the crop and sex of respondent, more than 50% of the farmers use informal seed sources (Table 2 and Appendix A Figure A1). Significantly more women use seed from their own farm for beans and sorghum in Kenya, and Tanzania, respectively. While, for sorghum seed, significantly more men use seed companies in Kenya and extension services in Tanzania

(Appendix A Table A3). Overall, more than three-quarters of the respondents use either seed from their own farm or from a neighbor.

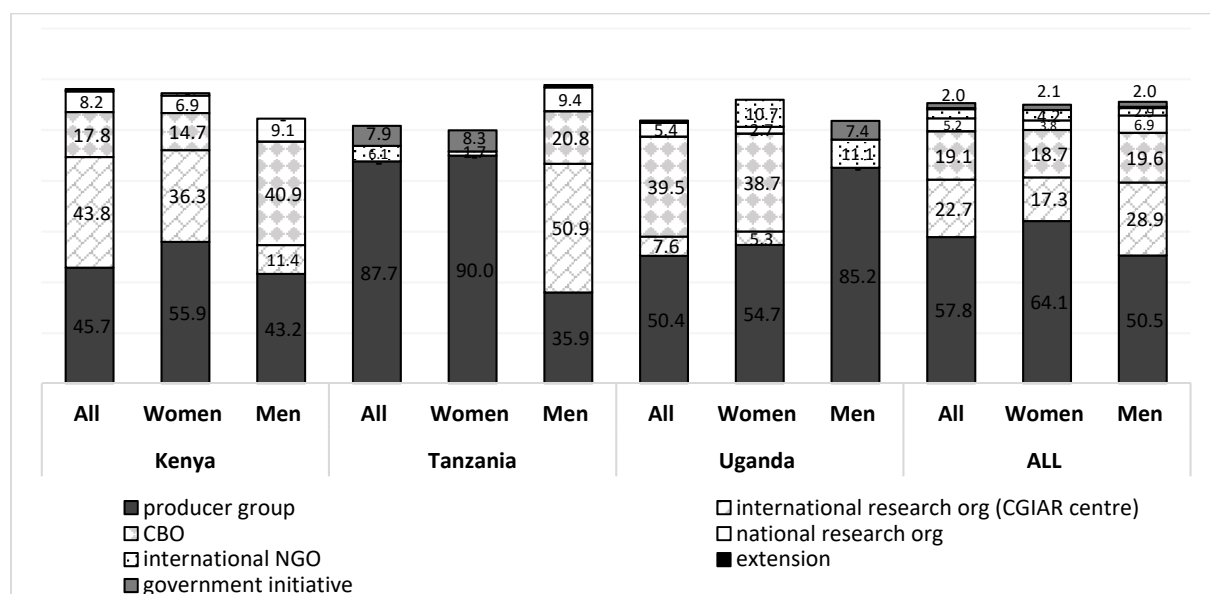
**Table 2.** Sources of seed by crop (% of respondents) <sup>a</sup>, (a gender-disaggregated analysis is presented in Appendix A Figure A1 and Table A3).

	N	Own Seed	Neighbour or Fellow Farmer	Local Market	Extension Services	Seed Company	Farmer Group
Beans	725	62.1 a	13.8 a	53.9	1.7 a	5.8 a	8.7 a
Finger millet	206	71.8 b	28.6 b	9.2 a	7.3 bc	5.8 ab	13.6 ab
Forage legumes	20	40.0	30.0 ab	5.0 ab	0.0 ab	20.0 c	25.0 b
Sorghum	590	66.8 ab	31.9 b	21.5 b	10.8 c	8.6 bc	14.1 b
All	959	64.9	22.9	34.9	5.9	7.1	11.6

<sup>a</sup> Multiple responses were possible hence the reported percentages per crop are higher than 100%; Column means followed by the same letter are not significantly different at the 5% level using Tukey’s tests.

4.5. Institutional Dynamics in Access to Information and Seed

Respondents were asked to indicate whether they were actively involved in any type of organization in the three years prior to the survey and to specify which one(s) they obtained seed from and the type of seed obtained. The data show that just over half of the men (50.7%) compared to 41% of women belonged to a group or organization. Farmers mentioned several organizations they were involved in, which include producer groups (such as women’s groups, men’s groups, self-help groups, environment-oriented groups, village savings and loan groups, cooperatives, village community banks), community-based organizations (CBOs), international research organizations or initiatives/programs (e.g., International Center for Tropical Agriculture (CIAT)/CGIAR and CCAFS), national agricultural research organizations (National Agricultural Research Organization (NARO) in Uganda, Kenya Agricultural and Livestock Research Organization (KALRO) and Kenya Agricultural Research Institute (KARI) in Kenya), government social protection initiatives (Tanzania Social Action Fund) and international NGOs (e.g., BRAC, Inades-Formation) (Figure 4, Appendix A Table A4). Thirty-three percent of respondents (*n* = 595) indicated that they obtained seed varieties from one or more of the above-mentioned organizations.



**Figure 4.** Formal and informal institutions used as seed sources.

In Kenya and Uganda, farmers mention CGIAR Centres and affiliated initiatives (CIAT and CCAFS) as seed sources; however, a higher percentage of farmers in Kenya seem to have had more extensive access (Appendix A Figure A2). CCAFS has been working in the study communities that have been part of various projects, which has allowed farmers the freedom to access and use a broad variety of plant genetic material. More women (64.1%) compared to men (57.8%) mention access through producer organizations, which are mostly informal. On the other hand, men seem to use more formal seed sources, such as national and international research organizations—a significantly higher proportion of men in Kenya and Tanzania access these organizations (Appendix A Table A4). Community-based organizations are also mentioned as a seed source and a higher proportion of men compared to women use this source. CBOs are non-profit organizations that operate and provide social services (such as education, health, gender issues, rights of disabled, etc.) at the local level and rely mostly on voluntary contributions [49]. CBOs are generally smaller than NGOs, but larger than producer organizations, and can be important avenues for accessing markets, extension and finance [50]. None of the respondents mentioned the private sector in this section of the survey; no formal sources were mentioned because the leading question was on the organizations that farmers were involved in and they are not likely to be ‘involved’ in any private sector organizations, but are likely ‘access goods and services’ from such organizations.

#### 4.6. Formal Sources of Information about Seeds

In order to understand how farmers interact with experts, respondents were asked to name ‘experts’ from formal institutions (who are not farmers) with whom they discussed and from whom they obtained information about seed for the sorghum, beans, finger millet and forage legumes that they were growing (“Please name up to three experts (who are not farmers) with whom you discuss [name of crop] seed.”). In addition, respondents had to indicate the name of the institute that the expert was affiliated with, and the specific crop and names of the varieties discussed with the expert. In total, only 207 respondents (96 women and 111 men), which is about 21% of the total sample size, fully answered both questions, indicating that a fairly small proportion of all interviewed farmers discuss seed-related matters with individuals they would perceive as experts. This section summarizes information from the 207 respondents. The total number of men and women who provided information in each of the countries are as follows: Kenya (137 total—72 women, 65 men); Tanzania (41 total—9 women, 32 men); Uganda (29 total—15 women and 14 men). When the analysis is disaggregated by sex and country, there are discrepancies in the proportion of men and women (Appendix A Table A5); in Tanzania, more men (80.9%) reported interaction with experts, whilst in Kenya and Uganda it was an almost equal proportion with 52.9% and 56.3% of the respondents in the respective countries being women.

Farmers mentioned experts affiliated with international agricultural research organizations or initiatives (CIAT, International Food Policy Research Institute (IFPRI), CCAFS), international NGOs (World Neighbors), national agricultural research organizations (Tanzania Agricultural Research Institute (TARI), NARO including Zonal Agricultural Research and Development Institutes (ZARDIs), KARI and KALRO), extension agents (village, district/municipal and country level), private sector (Mount Meru Millers Ltd., Singida, Tanzania), producer organizations and CBOs. The latter two (producer organizations and CBOs) could refer to experts that are called in to advise the groups). Given that farmers in different countries have access to experts affiliated with diverse organizations, the results have been presented at the county level. In Kenya, most farmers (67.2%) mentioned experts from international agricultural research organizations and more women had access compared to men (75% vs. 58.5%;  $p = 0.040$ ). Kenyan farmers were the only ones who indicated they discussed seed information with international NGO experts and specifically mentioned an NGO called World Neighbors. In Tanzania, extension agents from the Ministry of Agriculture were the most mentioned (82.9%), followed by national agricultural research organizations (24.4%). There were no significant differences in the percentage of

men and women. Only three farmers (one woman and two men) in Tanzania mentioned private sector experts (Mount Meru Millers Ltd.). In Uganda, national agriculture research organization experts were the most mentioned (75.9%). One female respondent in Uganda mentioned a private sector expert based in the capital city of Kampala but did not specify the name of the company/organization.

As a follow up to the question about experts, and to gather information to help us understand gender-based differences in the choices of crops and varieties used to cope with climate change, farmers were asked to indicate the crops and varieties they discussed with the experts. From the 207 respondents who indicated that they had interacted with experts, 156 (47% men) were able to name the specific crops and varieties. This section is, thus, based on the analysis of these 156 farmers' responses, the majority of whom were from Kenya (81%) and only 13% and 6% from Tanzania, and Uganda, respectively. Although, farmers mentioned several varieties, it is possible they reported varieties they had accessed through the experts, even though the question was specifically about discussions. No information regarding the content and nature of the discussions was collected. However, discussions could have been related to various aspects, such as procurement, use, benefits, pest and disease-specific to the crop and/or variety, amongst others. In total, 36 varieties were reported (18 beans, 16 sorghum and 3 finger millet). Men mentioned more sorghum varieties compared to women (16 vs. 8, respectively). In general, men and women farmers in the three countries mentioned the same varieties. There are a few instances where some were exclusively mentioned by either gender and there were some minor differences in the proportion who mentioned a specific variety. Some varieties seemed more popular than others; for example, improved varieties such as *Rosecoco* bean and *Seredo* sorghum (mentioned by 35% and 30%, respectively, in Kenya), and *Marcia* sorghum (mentioned by 41% of men in Tanzania; none of the women mentioned it). Varietal preferences can be attributed to socio-economic factors, variety characteristics, consumer demand, climatic conditions and seed availability. Most farmers (both men and women) indicated that they discussed the improved varieties *Rosecoco* bean and *Seredo* sorghum with international organizations, in particular CGIAR Centers. CBOs were also mentioned as one of the main institutes where farmers discussed *Seredo* sorghum, highlighting the importance of community networks for information on, and access to, improved varieties. While, for *Marcia* sorghum, the male farmers indicated that they discussed the variety with extension agents.

The socio-demographic characteristics of the 207 respondents who indicated that they interacted with experts are presented in Table 3 (Refer to Table A6 for country level analyses). Almost all the respondents had access to an information asset. A higher proportion (92%) of the respondents were older (>31 years), which perhaps suggest that youth has limited access to experts. There is a need for further research and assess why younger people have limited interaction with experts in these communities. One reason could be that many of them have migrated to the city or found nearby jobs. Most of the farmers who interacted with experts had secondary education (42.7% of women and 30% of men). The majority were married (74% women and 94.6% of men).

**Table 3.** Socio-demographic characteristics of farmers who interacted with experts (% of respondents).

		ALL (n = 207)	Women (n = 96)	Men (n = 111)	t-Value	p
Information assets	Access to any information asset	92.8	95.8	90.1	1.592	ns
	Mobile phone	87.9	91.7	84.7	1.534	ns
	Radio	71.0	74.0	68.5	0.867	ns
	TV	16.0	13.5	18.2	0.903	ns
Age	Teenage/youth ( $\leq 0$ yrs)	0.5	1.1	-	0.281	ns
	Young adults (21–30 yrs)	7.8	8.4	7.2	0.323	ns
	Middle-aged (31–45 yrs)	38.4	36.8	39.6	0.410	ns
	Older adults (>45 yrs)	53.4	53.7	53.2	0.076	ns
Education level	No education	3.9	3.1	4.6	0.524	ns
	Basic education <sup>a</sup>	25.7	30.2	21.8	1.374	ns
	Completed primary school	18.9	11.5	25.5	0.259	**
	Some secondary school	35.9	42.7	30.0	1.904	*
	Other	15.5	12.5	18.2	1.121	ns
Marital status	Divorced	0.5	-	0.9	0.930	ns
	Married	85.0	74.0	94.6	4.313	***
	Single	3.9	7.3	0.9	2.400	**
	Widowed	10.6	18.8	3.6	3.619	***

<sup>a</sup> has some years of primary schooling, able to read; \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ , ns = not significant.

## 5. Discussion

There are some differences and similarities in seed system dynamics in the targeted sites, being Kenya, Tanzania and Uganda. There are differences within and between countries regarding the formal and informal seed sources and varieties used by men and women farmers to cope with climate change effects. However, the results indicate the importance of both formal and informal institutions in helping farmers and agricultural systems cope with climate change, specifically with respect to accessing and disseminating targeted seed and information for men and women farmers. This is similar to findings by [51], who highlighted the close collaboration between formal and informal seed sector actors in the breeding and dissemination of viable seed varieties in Mali.

Men and women farmers are equally affected by climate-change related effects, which include droughts, short rainy seasons, and pests and diseases. Farmers use specific varieties of beans, sorghum, finger millet and forage legumes to cope with some of these effects. The results seem to indicate gendered responsibilities and access to crop varieties perceived to be adapted to climate change—beans for women and sorghum for men. The various climate-adapted varieties mentioned by farmers in the three countries can be used to facilitate participatory evaluations to assess adaptability in other target environments where they are currently not being grown. Improved varieties, which may be high yielding, have resistance to pests and diseases and/or might have other attributes that are important for climate-change adaptation are mentioned by both men and women with differences in level of access by country. A related study in Ghana revealed that that the adoption of early-maturing seed varieties was high for males compared to females [52] whilst another study conducted in Benin found that more women compared to men used improved varieties to cope with climate change [53]. Similarly, women farmers in Kenya were more conversant with quality traits and preferred local maize varieties over the modern ones compared to their male counterparts [12]. In our study, no common variety was mentioned in all the three countries and very few were identified in two countries. Given that specific varieties are not mentioned in all sites, deliberate efforts can be made to facilitate the evaluation of varieties that might be well adapted to other areas and meet farmer-specific needs. This would enable the exchange and increased diversity for supporting climate-change adaptation in areas where farmers are not already growing them.

Differences in varieties mentioned and proportions can be attributed to differing preferential weights that women and men place on different characteristics of the varieties, dif-



ferent roles in the value chain, end-use and whether the same crop or variety is being grown under different conditions [54]. The results are similar to a study by [55] who reported differences in the selection criteria for sorghum varieties by men and women farmers in Kenya. In that study, more women than men rated early maturity (64.5% vs. 53.3%, respectively), seed colour (85.7% vs. 30%, respectively), tolerance to *Striga* weed (63.4% vs. 54.2%, respectively) as important. Whereas, more men than women rated yield (64.3% vs. 53.3%, respectively) and taste/satiety value (38.9 vs. 25%, respectively) as key characteristics. In another study carried out in Niger, women, who are mostly responsible for threshing and processing household consumption indicated a preference for pearl millet varieties that are easy to thresh. While, men who were responsible for gathering and using stalks for livestock feeding and construction preferred millet varieties with thin stalks [56]. Social ties and networks play a critical role in providing seed and information related to climate-change adaptation for both men and women. Informal sources of seed and information, such as producer groups and the local markets, were highlighted as important particularly for women as they rely heavily on kinship and social ties and informal seed sources, compared to men. The proportion of women relying on informal seed sources, which include own farm and/or neighbor/fellow farmer, was significantly higher in all three countries compared to men. This study shows that formal institutions, such as international and national research organizations, which often develop and disseminate improved varieties are more accessible to men. Social network analysis with the same study participants shows that in all sites, women had more connections with other women with greater access to local varieties. Whereas, men were more likely to exchange seed and information amongst themselves with more access to improved varieties [6].

The study explored the dynamics at play in access to information about seed and varieties. There are discrepancies in terms of access to what farmers perceive as 'experts' who are affiliated with formal institutions. The results indicate that perceived experts are accessible to both men and women, but the level of access differs by country. Overall, men seem to have more access to extension services, whilst more women have access to international agricultural research organizations. In Kenya, more women indicated that they interacted with and discussed information about seeds with experts from international agricultural research organizations; in Tanzania, extension agents from the Ministry of Agriculture and national agricultural research organizations were the most mentioned by both men and women, with no significant differences in the frequency of the responses of men and women; in Uganda, national agriculture research organization experts were mentioned more than others and the proportion of women indicating this interaction was higher.

The majority of farmers in our study practice subsistence agriculture. It is important to assess gender issues in agricultural and rural development with clear reference to the quality and nature of economic relations within such subsistence agricultural households. For example, understanding sex-disaggregated allocation and division of labor, labor efficiency, productivity, technical efficiency and how they intersect with seed access and use can provide a comprehensive picture to inform the most appropriate seed systems interventions in a particular context. A study carried out in Nepal showed that men were more productive partly as they had control over better land and access to new technology such as improved seed [57].

## 6. Conclusions and Recommendations

The study reiterates the need for context-specific assessments and recommendations. Informal institutions, such as producer organizations and farmer groups, act as an interface between farmers and formal institutions. They play a key role in seed systems, supporting the dissemination of varietal information and seed, and are more accessible to women farmers. Therefore, any interventions in the seed system should ideally target this interface. The role of these informal institutions could be strengthened by building on existing strong

network ties, improving access to information in the networks and these institutions, and strengthening their engagement with formal institutions such as research organizations.

This study highlights the need for inclusiveness and gender-responsive seed systems. In order to ensure equitable outcomes and increase women's participation and empowerment, seed system interventions in the informal, formal and intermediate seed systems should deliberately target both men and women of different social categories. Access to improved varieties and quality seed, hybrid seed distribution, participatory training programs, varietal evaluation and information dissemination should be equally available to farmers of both sexes. Understanding the underlying reasons for discrepancies and gender biases in access and the use of quality and improved planting material in the heterogeneous contexts, are essential for informing, and thereby, enhancing adoption.

There is a need to promote and build the capacity of seed producer groups at the grassroots level and link them to other actors in the seed value chain from a gender perspective. This could be done by building on the existing social networks within the informal seed systems.

Limitations of this study include the reliance on a snowball sampling approach, which may miss some especially isolated farmers who are not part of the surveyed networks. Our study is also limited by the way the network is defined—as an in-person exchange of seed or information about seed. This may disregard the potentially important roles of electronic information and social media linkages increasingly available to farmers regardless of context. Future similar studies can take this into account during study design. Although there are some limitations in the analytical methods used, partly due to differences in sample size, challenges of assessing some interactions due to the categorical nature of the variables; the study overall provides valuable information on seed systems.

Smallholder and subsistence farming communities are likely to suffer climate change impacts that are locally specific and hard to predict [58]. Policies that ensure farmers are aware and effectively using climate-smart technologies are essential for mitigating the impacts of climate-related shocks and for enhancing seed system and smallholder farmer resilience. Such policies and related seed interventions should be designed from a gender perspective. For instance, community-level seed multiplication and seed saving systems such as seed pass-on programs and conservation initiatives through community seed banks, could be designed in such a way that they empower women farmers as key actors in seed value chains, through targeted training and tailor-made input and service delivery.

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**Institutional Review Board Statement:** This study was conducted according to the guidelines of the Declaration of Alliance of Bioversity International and CIAT.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

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## Appendix A

**Table A1.** Demographic and socio-economic characteristics of survey respondents.

		All ( <i>n</i> = 996) <sup>a</sup>	Women ( <i>n</i> = 584)	Men ( <i>n</i> = 412)	chi	<i>p</i>
		%	%	%		
<b>Individual Characteristics</b>						
Age	Teenage/youth (<20 yrs)	0.8	1.0	0.5	1.700	ns
	Young adults (21–30 yrs)	9.3	9.8	8.5		
	Middle aged (31–45 yrs)	35.4	34.4	36.7		
	Older adults (>45 yrs)	54.5	54.7	54.3		
Education level	No education	18.4	19.8	16.5	11.676	0.020 **
	Basic education <sup>b</sup>	22.3	22.9	21.6		
	Completed primary school	36.1	35.4	37.1		
	Some secondary school	19.9	20.3	19.4		
	Other	3.2	1.72	5.3		
Marital status	Single	7.7	10.3	3.9	91.906	0.000 ***
	Married	75.9	65.5	90.5		
	Divorced	3.0	4.0	1.7		
	Widowed	13.1	20.1	3.2		
	Cohabiting	0.4	0.2	0.7		
Relationship of respondent to household head	Household head	57.3	31.9	93.5	401.686	0.000 ***
	Spouse	37.2	62.3	1.5		
	Other family member	5.4	5.7	5.1		
	Other non-family member	0.1	0.2	-		
Membership to an organization	Actively involved in a group/organization/association related to farming during the past 3 yrs.	45.4	41.6	50.7	8.184	0.004 ***
<b>Household Characteristics</b>						
		Mean (S.D)	Mean (S.D)	Mean (S.D)	Min, Max	<i>p</i> <sup>c</sup>
Household size		6.2 (2.9)	6.0 (2.9)	6.4 (2.8)	1, 19	0.026 **
Distance to nearest market (km)		0.2 (0.7)	0.2 (1.5)	0.1 (0.4)	0.001, 41.5	0.007 ***
Distance to nearest city/town (km)		0.3 (2.9)	0.2 (0.8)	0.5 (4.2)	0.001, 6.5	ns
Distance to the nearest road (km)		0.2 (0.5)	0.3 (0.6)	0.1 (0.4)	0.000, 3.5	0.000 ***
		%	%	%	chi	<i>p</i>
Asset ownership	Household owns/has access to an information asset (TV, radio, mobile phone)	88.5	86.1	91.8	7.464	0.006 ***
	TV	12.5	10.7	15.3	4.583	0.032 **
	Radio	68.7	63.8	75.3	14.599	0.000 ***
	Mobile phone	80.8	79.3	82.9	2.100	ns
Land use	Crops	99.4	99.3	99.5	0.161	ns
	Grazing	54.9	48.3	63.8	22.185	0.000 ***
	Forestry	34.6	29.1	42.5	18.578	0.000 ***
	Residence	69.0	70.6	66.8	1.690	ns
Top five crops grown by households	Maize	94.0	93.2	95.2	1.698	ns
	Beans	74.9	73.6	76.7	1.210	ns
	Sorghum	63.1	61.8	64.8	0.928	ns
	Groundnuts	59.9	59.1	61.2	0.439	ns
	Cowpeas	48.8	48.3	49.5	0.146	ns

<sup>a</sup> some observations not included due to missing values; <sup>b</sup> has some years. of primary schooling, able to read; <sup>c</sup> for the continuous variables, differences between men and women tested using *t*-tests; \*\*\* *p*-value < 0.01, \*\* *p*-value < 0.05, ns = not significant.

**Table A2.** (a–c): Proportion of men and women who mentioned specific varieties they use to cope with climate change, by country and crop (% of respondents).

(a) Kenya					(b) Tanzania					(c) Uganda							
Variety	Crop <sup>x</sup>	All (n = 210)	Women (n = 101)	Men (n = 109)	p	Variety	Crop <sup>x</sup>	All (n = 103)	Women (n = 52)	Men (n = 51)	p	Variety	Crop <sup>x</sup>	All (n = 75)	Women (n = 49)	Men (n = 26)	p
Red sorghum(I)	S	29.1	28.7	29.4	ns	Macia(I)	S	68	71.2	64.7	ns	Seed Engufu(L)	B	77.3	75.5	80.8	ns
Mwezi mbili(I)	B	28.1	27.7	28.4	ns	Pato(I)	S	9.7	1.9	17.7	***	Kaita Bahuru(L)	B	9.3	12.2	3.9	ns
Andiwo(L)	S	10	10.9	9.2	ns	Hakika(I)	S	4.9	1.9	7.8	ns	White bean(I)	B	8	2	19.2	***
<b>Seredo(I)</b>	S	9.1	8.9	9.2	ns	Tegemeo(I)	S	4.9	5.8	3.9	ns	Seed endaira	B	6.7	8.2	3.9	ns
KAT B9 (I)	B	7.1	5.9	8.3	ns	Naco mtama 1(I)	S	3.9	3.9	3.9	ns	<b>Brown millet</b>	FM	4	4.1	3.9	ns
<b>Rosecoco(I)</b>	B	7.1	8.9	5.5	ns	Sandala(L)	S	2.9	5.8	-	*	Black beans	B	2.7	4.1	-	ns
Nyayo(I)	B	6.2	5.9	6.4	ns	Red millet	FM	1.9	1.9	2	ns	Bukalasa(I)	B	1.3	2	-	ns
Kajimbo Riat	S	5.7	7.9	3.7	ns	Soya fupi	B	1.9	3.9	-	ns	<b>Red beans</b>	B	1.3	2	-	ns
Ochuti(L)	S	5.2	5	5.5	ns	Wahi(I)	S	1.9	1.9	2	ns	Kalo	FM	1.3	2	-	ns
Nyakamusa(I)	S	3.8	4	3.7	ns	Combati	B	1	1.9	-	ns	Makerere	FM	1.3	2	-	ns
Yellow green	B	2.4	2	2.8	ns	Katumbwe	S	1	-	2	ns	Oburo	FM	1.3	2	-	ns
Serena(I)	S	1.9	2	1.8	ns	Kiburunge	FM	1	-	2	ns	<b>Wimbi 5</b>	FM	1.3	2	-	ns
Nyaela	B	1.4	3	-	*	Lugugu(L)	S	1	1.9	-	ns	<b>Seredo(I)</b>	S	1.3	2	-	ns
Yellow bean	B	1.4	1	1.8	ns	<b>Rosecoco(I)</b>	B	1	1.9	-	ns	mean no. of varieties		1.2	1.2	1.1	
Jowi	S	1.4	1	1.8	ns	Black & white cowpea(I)	FL	1	-	2	ns	total no. of varieties		13	13	5	
Jamuomo(L)	S	1.4	3	-	*	Red & white cowpea(I)	FL	1	-	2	ns	sorghum		1	1	0	
Mwezi moja(I)	B	1	2	-	ns	White cowpea(I)	FL	1	-	2	ns	beans		8	8	4	
Piriton	B	1	1	0.9	ns	mean no. of varieties		1.1	1	1.1		finger millet		4	4	1	

Table A2. Cont.

		(a) Kenya				(b) Tanzania					(c) Uganda						
Variety	Crop <sup>x</sup>	All (n = 210)	Women (n = 101)	Men (n = 109)	p	Variety	Crop <sup>x</sup>	All (n = 103)	Women (n = 52)	Men (n = 51)	p	Variety	Crop <sup>x</sup>	All (n = 75)	Women (n = 49)	Men (n = 26)	p
<b>Red beans</b>	B	1	2	-	ns	total no. of varieties		17	12	12							
Chebiririet	B	0.5	-	0.9	ns	sorghum		9	8	7							
Saitoti(I)	B	0.5	-	0.9	ns	beans		3	3	0							
Sura mbaya	B	0.5	-	0.9	ns	finger millet		2	1	2							
Wairimo	B	0.5	-	0.9	ns	forage legumes		3	-	3							
Cheplalachek	FM	0.5	1	-	ns												
<b>Wimbi 5</b>	FM	0.5	-	0.9	ns												
<b>Brown millet</b>	FM	0.5	-	0.9	ns												
Chepnyaliliet	S	0.5	1	-	ns												
Gooseneck(I)	S	0.5	-	0.9	ns												
JBK 108	S	0.5	-	0.9	ns												
Chepsangarar	S	0.5	-	0.9	ns												
mean number of varieties		1.3	1.3	1.3													
total no. of varieties		24	21	30													
sorghum		11	10	11													
beans		11	10	11													
finger millet		2	1	3													

<sup>x</sup> B = beans, S = sorghum, FM = finger millet, FL = forage legumes; L = local, I = improved or introduced; Chi-square tests used to assess if there is a significant association between the respondent sex and varieties they mentioned; \*\*\*  $p < 0.01$ , \*  $p < 0.1$ , ns = not significant; **Bold** = Varieties mentioned in at least one country—*Rosecoco* beans (Kenya and Tanzania); Red beans, *Seredo* sorghum, *Wimbi 5* finger millet, Brown millet (Kenya and Uganda).



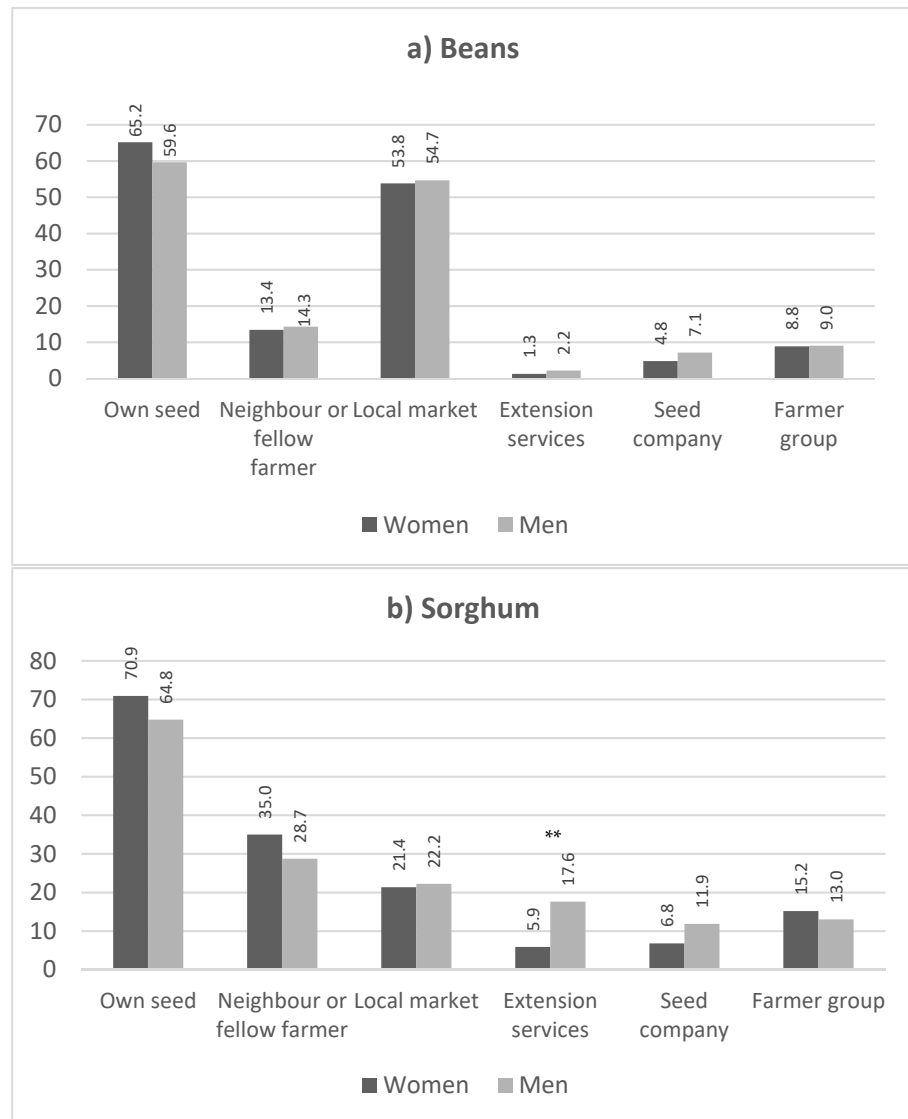
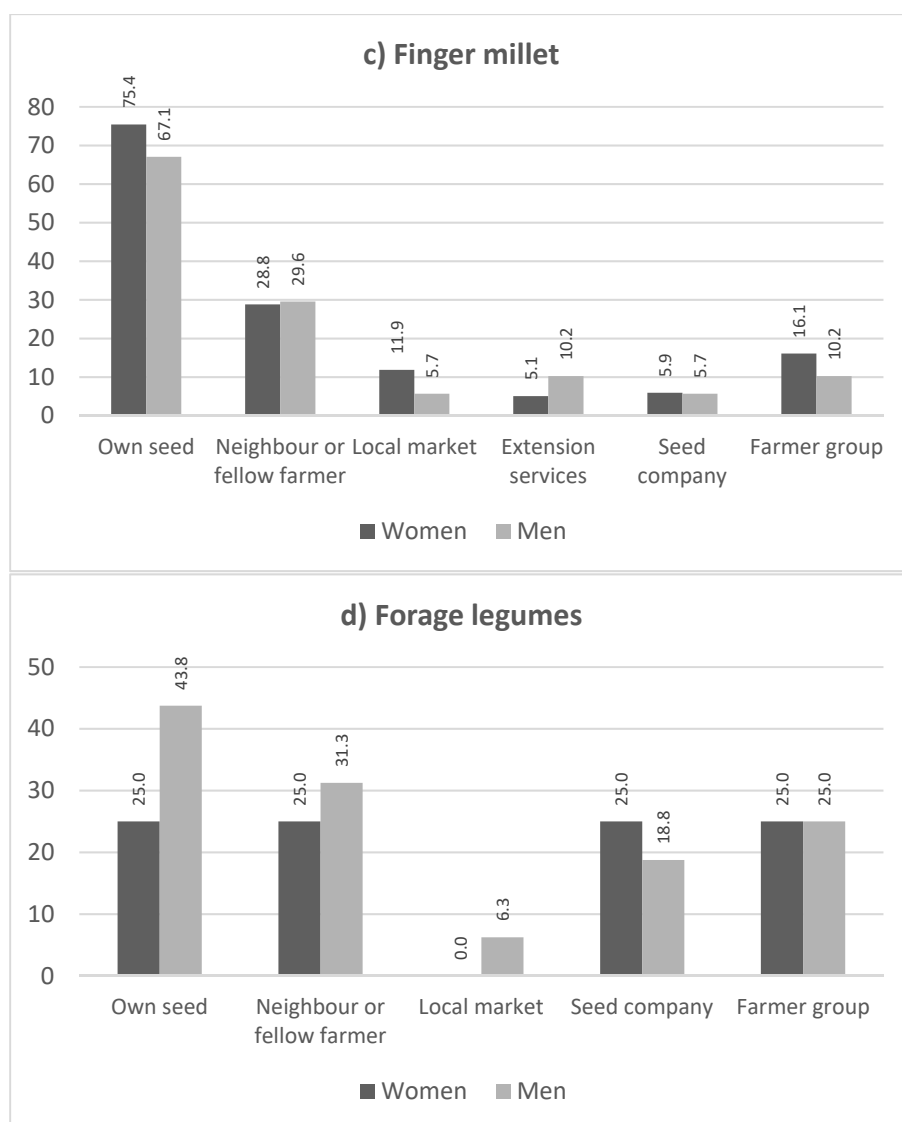
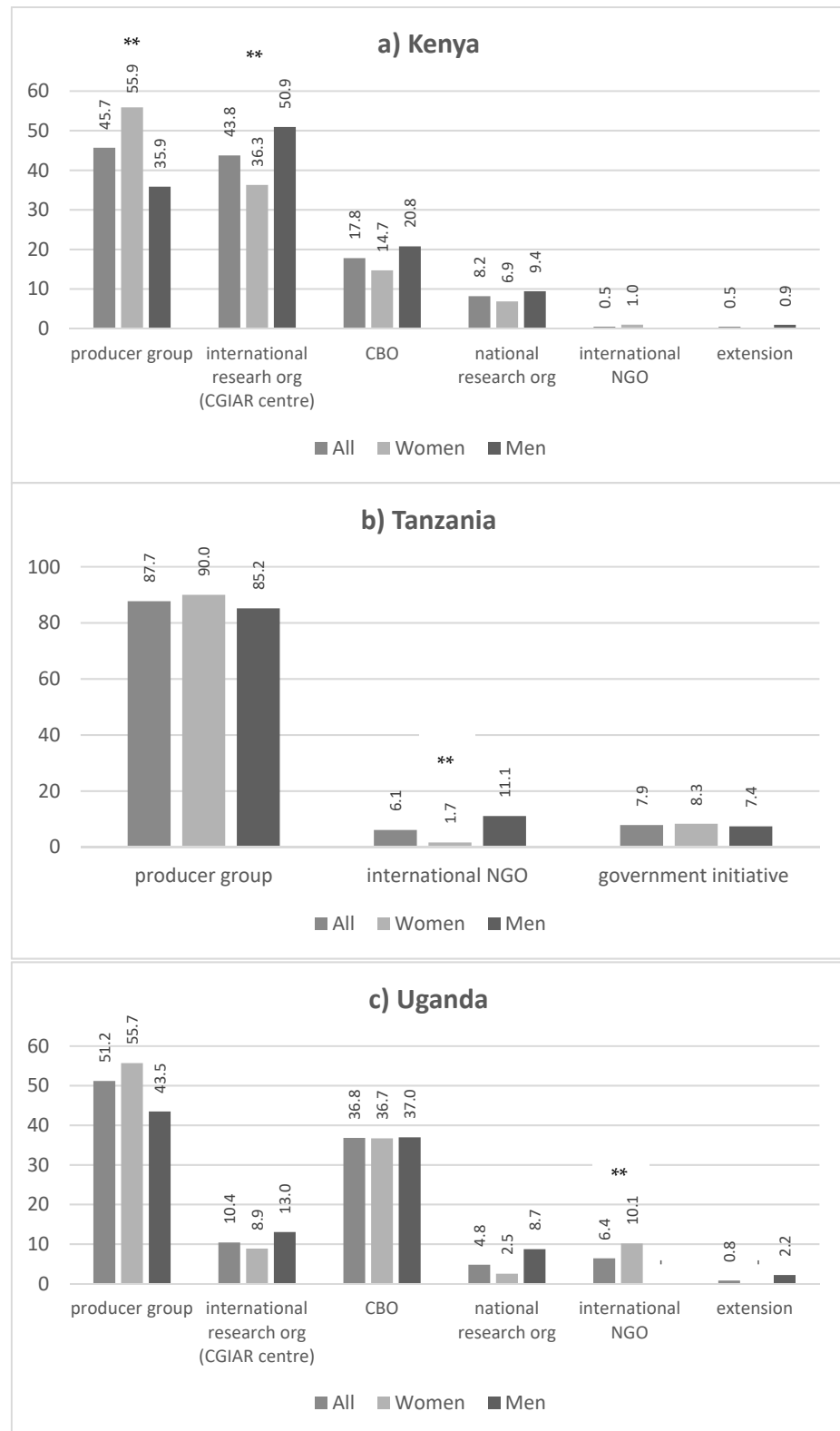


Figure A1. Cont.



**Figure A1.** Seed sources by crop and sex (% of respondents) for (a) beans, (b) sorghum, (c) finger millet and (d) forage legumes. Chi square tests did not show any significant association between a specific seed source and respondent sex except for sorghum-extension services (\*\*  $p < 0.05$ ).



**Figure A2.** Formal institutions used as seed sources, by sex and country (% of respondents) in (a) Kenya, (b) Tanzania and (c) Uganda. Overall, chi square tests show a significant association between the seed sources and respondent sex in Kenya and Uganda at the 5% level. \*\* indicates a significant difference in the proportion of men and women who mentioned that seed source at the 5% level using *t*-tests.

**Table A3.** Seed sources by crop, sex and country (% of farmers).

Crop	Country	Seed Source	All	Women	Men	t-Value	Chi (Overall)			
Beans	Kenya	N	304	164	140					
		Own seed	51.0	55.5	45.7	1.701 *	32.47 *			
		Neighbor or fellow farmer	17.8	16.5	19.3	ns				
		Local market	56.6	51.8	62.1	1.812 *				
		Extension services	1.6	1.2	2.1	ns				
		Seed company	13.2	11.0	15.7	ns				
	Farmer group	20.7	21.3	20.0	ns					
	Tanzania	N	156	85	71					
		Own seed	55.8	54.1	57.8	ns	ns			
		Neighbor or fellow farmer	14.1	15.3	12.7	ns				
		Local market	52.6	51.8	53.5	ns				
		Extension services	3.9	2.4	5.6	ns				
		Seed company	0.6	0.0	1.4	ns				
	Uganda	N	259	150	109					
		Own seed	79.2	80.0	78.0	ns	ns			
		Neighbor or fellow farmer	8.9	8.7	9.2	ns				
		Local market	51.7	55.3	46.8	ns				
		Extension services	0.4	0.7	0.0	ns				
Seed company		0.4	0.7	0.0	ns					
Finger millet	Kenya	N	108	64	44					
		Own seed	72.2	76.6	65.9	ns	ns			
		Neighbor or fellow farmer	28.7	29.7	27.3	ns				
		Local market	5.6	7.8	2.3	ns				
		Seed company	11.1	10.9	11.4	ns				
		Farmer group	25.9	29.7	20.5	ns				
	Tanzania	N	56	24	32					
		Own seed	64.3	66.7	62.5	ns	ns			
		Neighbor or fellow farmer	26.8	20.8	31.3	ns				
		Local market	3.6	8.3	0.0	1.675 *				
		Extension services	26.8	25.0	28.1	ns				
		Uganda	N	42	30	12				
	Own seed		81.0	80.0	83.3	ns		ns		
	Neighbor or fellow farmer		33.3	33.3	33.3	ns				
	Local market		26.2	23.3	33.3	ns				
	Forage legumes		Kenya	N	13	3	10			
				Own seed	15.4	0.0	20.0		ns	ns
		Neighbor or fellow farmer		30.8	33.3	30.0	ns			
Seed company		30.8		33.3	30.0	ns				
Farmer group		38.5		33.3	40.0	ns				
Tanzania		N		7	1	6				
		Own seed	85.7	100.0	83.3	ns	ns			
		Neighbor or fellow farmer	28.6	0.0	33.3	ns				
		Local market	14.3	0.0	16.7	ns				
		Sorghum	Kenya	N	330	186		144		
				Own seed	57.3	62.4		50.7	2.134 **	ns
Neighbor or fellow farmer				32.7	35.0	29.9		ns		
Local market				32.7	30.7	35.4	ns			
Extension services				0.3	0.5	0.0	ns			
Seed company				15.5	11.8	20.1	2.079 **			
Farmer group			25.2	26.3	23.6	ns				
Tanzania			N	257	140	117				
			Own seed	78.6	77.1	80.3	ns	27.13 ***		
	Neighbor or fellow farmer		31.1	34.3	27.4	ns				
	Local market		7.4	8.6	6.0	ns				
	Extension services		24.5	12.9	38.5	4.956 ***				

t-tests used to assess if there were significant differences in the proportion of men and women who mentioned a specific source; chi square tests used to assess if there is an overall significant association between respondent sex and seed source mentioned for each crop and country; \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ , ns = not significant; only sources mentioned for a specific crop are included in table.

**Table A4.** Formal sources of seed (% of respondents)—statistical tests for results presented in Figure 3.

	Kenya				Tanzania				Uganda			
	Women (n = 102)	Men (n = 106)	t-Value	chi	Women (n = 60)	Men (n = 54)	t-Value	chi	Women (n = 75)	Men (n = 44)	t-Value	chi
CBO	14.7	20.8	ns	17.506 **	-	-	-	ns	38.7	38.6	ns	15.214 **
Extension	0.0	0.9	ns		-	-	-		0.0	2.3	ns	
Government intervention	-	-	-		8.3	7.4	ns		-	-	-	
International NGO	1.0	0.0	ns		1.7	11.1	2.120 **		10.7	0.0	2.273 **	
International agric. res. organization	36.3	50.9	2.145 **		-	-	-		5.3	11.4	ns	
National agric. research organization	6.9	9.4	ns		-	-	-		2.7	9.1	ns	
Private sector	-	-	-		-	-	-		-	-	-	
Producer organization	55.9	35.8	2.946 ***		90.0	85.2	ns		54.7	43.2	ns	

\*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , ns = not significant; *t*-tests used to assess if there were significant differences in the proportion of men and ad women who mentioned a specific source; chi square tests used to assess if there is an overall significant association between respondent sex and seed source mentioned in each country and for each crop.

**Table A5.** Affiliations of the experts with whom farmers discuss seed information (% of respondents).

	Kenya				Tanzania				Uganda				ALL			
	All (n = 137)	Women (n = 72)	Men (n = 65)	<i>p</i>	All (n = 41)	Women (n = 9)	Men (n = 32)	<i>p</i>	All (n = 29)	Women (n = 15)	Men (n = 14)	<i>p</i>	All (n = 207)	Women (n = 96)	Men (n = 111)	<i>p</i>
CBO	26.3	19.4	33.9	*	-	-	-		-	-	-		17.4	14.6	19.8	ns
Extension	1.5	-	3.1	ns	82.9	66.7	87.5	ns	10.3	6.7	14.3	ns	18.8	7.3	28.8	***
International NGO	11.7	13.9	9.2	ns	-	-	-		-	-	-		7.7	10.4	5.4	ns
International agric. res. organization	67.2	75.0	58.5	**	-	-	-		6.9	-	14.3	ns	45.4	56.3	36.0	***
National agric. research organization	5.8	4.2	7.7	ns	24.4	22.2	25.0	ns	75.9	86.7	64.3	ns	19.3	18.8	19.8	ns
Private sector	-	-	-		7.3	11.1	6.3	ns	3.5	6.7	-	ns	1.9	2.1	1.8	ns
Producer organization	0.7	1.4	-	ns	-	-	-		13.8	20.0	7.1	ns	2.4	4.2	0.9	ns
Overall chi square test				**				ns								ns

\*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ , ns = not significant; Multiple responses were possible hence the reported percentages are higher than 100%; Differences in the proportion of men and women are tested by using *t*-tests. For each country, chi square tests were done to test if there is a significant association between the respondent sex and affiliations of the experts, they interacted with—only Kenya showed a significant association.

**Table A6.** Socio-demographic characteristics of farmers who interacted with experts by sex and country (% of respondents).

		Kenya				Tanzania				Uganda			
		All (n = 137)	Women (n = 72)	Men (n = 65)	<i>p</i>	All (n = 41)	Women (n = 9)	Men (n = 32)	<i>p</i>	All (n = 29)	Women (n = 15)	Men (n = 14)	<i>p</i>
Information assets	Access to any information asset	94.2	94.4	93.8	ns	85.4	100.0	81.3	ns	96.6	100.0	92.9	ns
	Mobile phone	89.1	88.9	89.2	ns	78.1	100.0	71.9	*	96.6	100.0	92.9	ns
	Radio	73.0	75.0	70.8	ns	61.0	77.8	56.3	ns	75.9	66.7	85.7	ns
	TV	11.7	11.1	12.5	ns	24.4	44.4	18.8	ns	24.1	6.7	42.9	**
Age	Teenage/youth (<20 yrs)	-	0.0	0.0	ns	-	0.0	0.0		3.5	6.7	0.0	ns
	Young adults (21–30 yrs)	9.5	11.3	7.7	ns	2.4	0.0	3.1	ns	6.9	0.0	14.3	ns
	Middle-aged (31–45 yrs)	36.5	32.4	41.5	ns	39.0	55.6	34.4	ns	44.8	46.7	42.9	ns
	Older adults (>45 yrs)	53.3	56.3	50.8	ns	58.5	44.4	62.5	ns	44.8	46.7	42.9	ns
Education level	No education	2.9	2.8	3.1	ns	7.3	11.1	6.3	ns	3.5	0.0	7.1	ns
	Basic education <sup>a</sup>	29.2	31.9	26.6	ns	9.8	11.1	9.4	ns	31.0	33.3	28.6	ns
	Completed primary school	13.1	11.1	15.6	ns	46.3	22.2	53.1	ns	6.9	6.7	7.1	ns
	Some secondary school	38.0	43.1	32.8	ns	22.0	33.3	18.8	ns	44.8	46.7	42.9	ns
	Other	16.1	11.1	21.9	*	14.6	22.2	12.5	ns	13.8	13.3	14.3	ns
Marital status	Divorced	-	0.0	0.0		-	0.0	0.0		3.5	0.0	7.1	ns
	Married	83.9	73.6	95.4	***	92.7	77.8	96.9	*	79.3	73.3	85.7	ns
	Single	2.2	2.8	1.5	ns	4.9	22.2	0.0	**	10.3	20.0	0.0	*
	Widowed	13.9	23.6	3.1	***	2.4	0.0	3.1	ns	6.9	6.7	7.1	ns

\*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ , ns = not significant; Differences in the proportion of men and women are tested by using *t*-tests; <sup>a</sup> has some years. of primary schooling, able to read.



## References

1. Abdul-Razak, M.; Kruse, S. The Adaptive Capacity of Smallholder Farmers to Climate Change in the Northern Region of Ghana. *Clim. Risk Manag.* **2017**, *17*, 104–122. [CrossRef]
2. Nelson, G.C.; Valin, H.; Sands, R.D.; Havlík, P.; Ahammad, H.; Deryng, D.; Elliott, J.; Fujimori, S.; Hasegawa, T.; Heyhoe, E.; et al. Climate Change Effects on Agriculture: Economic Responses to Biophysical Shocks. *Proc. Natl. Acad. Sci. USA* **2014**, *111*, 3274–3279. [CrossRef] [PubMed]
3. Prasad, P.V.V.; Staggenborg, S.A.; Ristic, Z. Impacts of Drought and/or Heat Stress on Physiological, Developmental, Growth, and Yield Processes of Crop Plants. In *Response of Crops to Limited Water: Understanding and Modeling Water Stress Effects on Plant Growth Processes*; Advances in Agricultural Systems Modeling; ASA-CSSA: Madison, WI, USA, 2008; pp. 301–355. ISBN 978-0-89118-188-0.
4. Lobell, D.B.; Gourdji, S.M. The Influence of Climate Change on Global Crop Productivity. *Plant Physiol.* **2012**, *160*, 1686. [CrossRef]
5. Adhikari, U.; Nejadhashemi, A.P.; Woznicki, S.A. Climate Change and Eastern Africa: A Review of Impact on Major Crops. *Food Energy Secur.* **2015**, *4*, 110–132. [CrossRef]
6. Otieno, G.; Zebrowski, W.M.; Recha, J.; Reynolds, T.W. Gender and Social Seed Networks for Climate Change Adaptation: Evidence from Bean, Finger Millet, and Sorghum Seed Systems in East Africa. *Sustainability* **2021**, *13*, 2074. [CrossRef]
7. Niles, M.T.; Mueller, N.D. Farmer Perceptions of Climate Change: Associations with Observed Temperature and Precipitation Trends, Irrigation, and Climate Beliefs. *Glob. Environ. Chang.* **2016**, *39*, 133–142. [CrossRef]
8. Kansime, M.K.; Mastenbroek, A. Enhancing Resilience of Farmer Seed System to Climate-Induced Stresses: Insights from a Case Study in West Nile Region, Uganda. *J. Rural Stud.* **2016**, *47*, 220–230. [CrossRef]
9. Cacho, O.J.; Moss, J.; Thornton, P.K.; Herrero, M.; Henderson, B.; Boudry, B.L.; Humpenöder, F.; Popp, A.; Lipper, L. The Value of Climate-Resilient Seeds for Smallholder Adaptation in Sub-Saharan Africa. *Clim. Chang.* **2020**, *162*, 1213–1229. [CrossRef]
10. Perez, C.; Jones, E.; Kristjanson, P.; Cramer, L.; Thornton, P.K.; Förch, W.; Barahona, C. How Resilient Are Farming Households and Communities to a Changing Climate in Africa? A Gender-Based Perspective. *Glob. Environ. Chang.* **2015**, *34*, 95–107. [CrossRef]
11. *ISSD Introduction to Integrated Seed Sector Development and Its Guiding Principles*; Centre for Development Innovation Wageningen UR: Wageningen, The Netherlands, 2004.
12. Christinck, A.; Rattunde, F.; Mulinge, W.; Weltzien, E. *Identifying Options for the Development of Sustainable Seed Systems: Insights from Kenya and Mali*; ZEF Working Paper Series; University of Bonn: Bonn, Germany, 2018.
13. IANGWE Gender Equality & Trade Policy. Available online: <https://www.un.org/womenwatch/feature/trade/#1> (accessed on 17 January 2021).
14. Adam, R.I.; Kandiwa, V.; David, S.; Muindi, P. *Gender-Responsive Approaches for Enhancing the Adoption of Improved Maize Seed in Africa: A Training Manual for Seed Companies*; CIMMYT: Texcoco, Mexico, 2019.
15. Galiè, A.; Jiggins, J.; Struik, P.C.; Grando, S.; Ceccarelli, S. Women’s Empowerment through Seed Improvement and Seed Governance: Evidence from Participatory Barley Breeding in Pre-War Syria. *NJAS-Wagening. J. Life Sci.* **2017**, *81*, 1–8. [CrossRef]
16. Kandiwa, V.; Adam, R.; Lweya, K.; Setimela, P.; Badstue, L.; Muindi, P. *Gender-Responsive Approaches for the Promotion of Improved Maize Seed in Africa*; CIMMYT: Texcoco, Mexico, 2018.
17. Brüntrup, M.; Heidhues, F. Subsistence agriculture in development: Its role in processes of structural change. In *Subsistence Agriculture in Central and Eastern Europe: How to Break the Vicious Circle*; Abele, S., Frohberg, K., Eds.; Studies on the Agricultural and Food Sector in Central and Eastern Europe; Institute of Agricultural Development in Central and Eastern Europe (IAMO): Halle, Germany, 2002; ISBN 3-9809270-2-4.
18. Lewis, W.A. Economic Development with Unlimited Supplies of Labour. *Manch. Sch.* **1954**, *22*, 139–191. [CrossRef]
19. Sadik-Zada, E.R. Distributional Bargaining and the Speed of Structural Change in the Petroleum Exporting Labor Surplus Economies. *Eur. J. Dev. Res.* **2020**, *32*, 51–98. [CrossRef]
20. Sadik-Zada, E.R. Natural Resources, Technological Progress, and Economic Modernization. *Rev. Dev. Econ.* **2021**, *25*, 381–404. [CrossRef]
21. Christinck, A.; Diarra, M.; Horneber, G. *Innovations in Seed Systems. Lessons from CCRP-Funded Project “Sustaining Farmer-Managed Seed Initiatives in Mali, Niger and Burkina Faso”*; McKnight Foundation: Minneapolis, MN, USA, 2014.
22. Mudege, N.N.; Torres, S. Gender Mainstreaming in Root Tuber and Banana Crops Seed Systems Interventions: Identification of Lessons Learnt and Gaps. *RTB Work. Pap.* **2017**. [CrossRef]
23. Kramer, B.; Galiè, A. *Gender Dynamics in Seed Systems Development*; PIM Synthesis Brief; International Food Policy Research Institute (IFPRI): Washington, DC, USA, 2020.
24. Reynolds, T.; Tobin, D.; Otieno, G.; McCracken, A.; Guo, J. Differences in Crop Selection, Resource Constraints, and Crop Use Values among Female-and Male-Headed Smallholder Households in Kenya, Tanzania, and Uganda. *J. Agric. Food Syst. Community Dev.* **2020**, *9*, 1–28. [CrossRef]
25. Beuchelt, T.D. Gender, social equity and innovations in smallholder farming systems: Pitfalls and pathways. In *Technological and Institutional Innovations for Marginalized Smallholders in Agricultural Development*; Springer: Cham, Switzerland, 2016; pp. 181–198.
26. Bob, U.; Babugura, A. Contextualising and Conceptualising Gender and Climate Change in Africa. *Agenda* **2014**, *28*, 3–15. [CrossRef]

27. Subedi, A.; Vernooy, R. Healthy food systems. In *Agrobiodiversity Index Report 2019: Risk and Resilience*; Bioversity, I., Ed.; Bioversity International: Rome, Italy, 2019; pp. 127–134. ISBN 92-9255-125-6.
28. Jost, C.; Ferdous, N.; Spicer, T.D. *Gender and Inclusion Toolbox: Participatory Research in Climate Change and Agriculture*; CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), CARE International and the World Agroforestry Centre (ICRAF): Copenhagen, Denmark, 2014.
29. Ngigi, M.W.; Mueller, U.; Birner, R. Gender Differences in Climate Change Adaptation Strategies and Participation in Group-Based Approaches: An Intra-Household Analysis from Rural Kenya. *Ecol. Econ.* **2017**, *138*, 99–108. [[CrossRef](#)]
30. IPCC. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Core Writing Team, Pachauri, R.K., Meyer, L.A., Eds.; IPCC: Geneva, Switzerland, 2014.
31. Habtezion, S. *Overview of Linkages between Gender and Climate Change*; CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), CARE International and the World Agroforestry Centre (ICRAF): Copenhagen, Denmark, 2013.
32. Wiggins, S.; Keats, S. *Leaping and Learning: Linking Smallholders to Markets in Africa*; Imperial College and Overseas Development Institute: London, UK, 2013.
33. Oxford Business Group. *Agriculture in Africa Report 2019*; Oxford Business Group: London, UK, 2019.
34. Nellemann, C.; Verma, R.; Hislop, L. *Women at the Frontline of Climate Change: Gender Risks and Hopes, a Rapid Response Assessment*; United Nations Environment Programme: Arendal, Norway, 2012; ISBN 82-7701-099-0.
35. Mulwa, C.; Marenya, P.; Rahut, D.B.; Kassie, M. Response to Climate Risks among Smallholder Farmers in Malawi: A Multivariate Probit Assessment of the Role of Information, Household Demographics, and Farm Characteristics. *Clim. Risk Manag.* **2017**, *16*, 208–221. [[CrossRef](#)]
36. McGuire, S.J. Securing Access to Seed: Social Relations and Sorghum Seed Exchange in Eastern Ethiopia. *Hum. Ecol.* **2008**, *36*, 217–229. [[CrossRef](#)]
37. Bernier, Q.; Meinzen-Dick, R.S.; Kristjanson, P.M.; Haglund, E.; Kovarik, C.; Bryan, E.; Ringler, C.; Silvestri, S. *Gender and Institutional Aspects of Climate-Smart Agricultural Practices: Evidence from Kenya*; CCAFS Working Paper No. 79; CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS): Copenhagen, Denmark, 2015.
38. Fisher, M.; Carr, E.R. 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.* **2015**, *35*, 82–92. [[CrossRef](#)]
39. Doss, C.R.; Morris, M.L. How Does Gender Affect the Adoption of Agricultural Innovations? The Case of Improved Maize Technology in Ghana. *Agric. Econ.* **2001**, *25*, 27–39. [[CrossRef](#)]
40. Ostrom, E. *Understanding Institutional Diversity*; Princeton University Press: Princeton, NJ, USA, 2005; ISBN 1-4008-3173-3.
41. Uphoff, N.; Buck, L. *Strengthening Rural Local Institutional Capacities for Sustainable Livelihoods and Equitable Development*; World Bank Group: Washington, DC, USA, 2006.
42. Tekalign, E. *Forage Seed Systems in Ethiopia: A Scoping Study*; International Livestock Research Institute (ILRI): Nairobi, Kenya, 2014.
43. Louwaars, N.P.; de Boef, S.W.; Edeme, J. Integrated Seed Sector Development in Africa: A Conceptual Framework for Creating Coherence between Practices, Programs, and Policies. *J. Crop Improv.* **2012**, *26*, 39–59. [[CrossRef](#)]
44. Zebrowski, W.; Lacasse, H.K.; Otieno, G.; Reynolds, T.W.; LaValle, N.; Baker-Wacks, E.; Klein, E. *Social Seed Networks and Climate Change Adaptation in East Africa*; Bioversity International: Rome, Italy, 2018.
45. Almekinders, C.J.; Louwaars, N.P. The Importance of the Farmers' Seed Systems in a Functional National Seed Sector. *J. New Seeds* **2002**, *4*, 15–33. [[CrossRef](#)]
46. Tadesse, Y.; Almekinders, C.J.; Schulte, R.P.; Struik, P.C. Tracing the Seed: Seed Diffusion of Improved Potato Varieties through Farmers' Networks in Chencha, Ethiopia. *Exp. Agric.* **2017**, *53*, 481–496. [[CrossRef](#)]
47. Mortimore, M.J.; Adams, W.M. Farmer Adaptation, Change and 'Crisis' in the Sahel. *Glob. Environ. Chang.* **2001**, *11*, 49–57. [[CrossRef](#)]
48. Mukasa, A.N.; Salami, A.O. Gender Equality in Agriculture: What Are Really the Benefits for Sub-Saharan Africa? *Afr. Econ. Brief.* **2016**, *7*, 1–12.
49. Chechetto-Salles, M.; Geyer, Y. *Community-Based Organisation Management: Handbook Series for Community-Based Organisations*; Institute for Democracy in South Africa: Cape Town, South Africa, 2006; ISBN 1-920118-18-7.
50. Marter, A.; Wandschneider, A. *The Role of NGOs and CBOs in Marketing in Uganda: The Potential in Remote Regions and in Reaching the Poor*; National Resources Institute: Greenwich, UK, 2002.
51. Rattunde, F.; Weltzien, E.; Sidibé, M.; Diallo, A.; Diallo, B.; Vom Brocke, K.; Nebié, B.; Touré, A.; Traoré, Y.; Sidibé, A. Transforming a Traditional Commons-Based Seed System through Collaborative Networks of Farmer Seed-Cooperatives and Public Breeding Programs: The Case of Sorghum in Mali. *Agric. Hum. Values* **2020**, *38*, 561–578. [[CrossRef](#)]
52. Adzawla, W.; Azumah, S.B.; Anani, P.Y.; Donkoh, S.A. Gender Perspectives of Climate Change Adaptation in Two Selected Districts of Ghana. *Heliyon* **2019**, *5*, e02854. [[CrossRef](#)]
53. Dah-gbeto, A.P.; Villamor, G.B. Gender-Specific Responses to Climate Variability in a Semi-Arid Ecosystem in Northern Benin. *Ambio* **2016**, *45*, 297–308. [[CrossRef](#)]
54. Weltzien, E.; Rattunde, F.; Christinck, A.; Isaacs, K.; Ashby, J. Gender and Farmer Preferences for Varietal Traits. In *Plant Breeding Reviews*; Goldman, I., Ed.; John Wiley & Sons, Ltd.: Hoboken, NJ, USA, 2019; pp. 243–278. ISBN 978-1-119-61680-1.

- 
55. Ndung'u, D.K. Mutagenesis and Development of Herbicide Resistance in Sorghum for Protection against Striga. Ph.D. Dissertation, University of KwaZulu Natal, Pietermaritzburg, South Africa, 2009.
  56. Baidu-Forson, J. On-Station Farmer Participatory Varietal Evaluation: A Strategy for Client-Oriented Breeding. *Exp. Agric.* **1997**, *33*, 43–50. [[CrossRef](#)]
  57. Aly, H.Y.; Shields, M.P. Gender and Agricultural Productivity in a Surplus Labor, Traditional Economy: Empirical Evidence from Nepal. *J. Dev. Areas* **2010**, *43*, 111–124. [[CrossRef](#)]
  58. Morton, J.F. The Impact of Climate Change on Smallholder and Subsistence Agriculture. *Proc. Natl. Acad. Sci. USA* **2007**, *104*, 19680–19685. [[CrossRef](#)] [[PubMed](#)]