Social Seed Networks and Climate Change Adaptation in East Africa

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Keywords: climate change, gender, East Africa, agriculture, seed network

Abstract

Climate change poses serious threats to smallholder farmers in East Africa, as increased temperatures and shorter periods of rainfall are generating consistently shorter growing seasons. As these conditions continue to worsen, it becomes increasingly imperative for smallholder farmers to utilize climate change adaptation strategies. East African farmers would benefit from having greater access to diverse seed varieties and information about climate change adaptation, which can be transferred through preexisting farmer information networks.

Our study investigates the routes of information flow through which smallholder exchange seed and information. We then examine how these exchanges among farmer networks can be improved. In order to examine the characteristics of these networks, our study analyzed household-level survey data collected by Bioversity International from sites in Kenya, Uganda, and Tanzania. Current seed sources and climate adaptation strategies were determined by creating summary statistics from the survey data. UCINET network analyses were conducted to acquire a more specific understanding of the current social networks among farmers. Seed networks were categorized by country, gender, and crop and then analyzed to determine where the distribution of seed and information can be improved and utilized.

Our findings suggest that farmers have a strong dependence on localized seed systems and have little influence from formal market sources. Although interactions between farmers are present from our UCINET analysis, farmers are most reliant on their own seeds instead of obtaining new seeds each season. Climate change is a clear obstacle that farmers are facing, with nearly all respondents indicating that they experience climate related challenges.

Overall, our results indicate that there are many ways to make improvements in the distribution of seed and information in Kenya, Uganda, and Tanzania. More policy efforts and resources could be directed towards informal and local systems, such as field days and agri-shows, which were listed as the main seed source by many respondents. Additionally, seed and information dissemination may be most effective through localized forms of seed exchange, such as local markets, organizations, and seed fairs. Since many respondents were involved in organizations, giving these organizations information about climate change adaptation to distribute to their members could be effective. Lastly, the high centrality networks in Kenya, specifically among females, offer opportunity to target individuals within networks to distribute resources. Strengthening farmer social seed networks is crucial in providing farmers with seeds and other farming practices necessary to be more resilient to climate change challenges.

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) estimates that global mean temperatures will increase between 1.4 to 5.8 degrees centigrade between 1990 and 2100, and that precipitation patterns will change considerably across the globe (IPCC 2014). Studies predict that these changes will have negative impacts on the productivity of crops in Sub Saharan Africa (Lobell et al 2015). In East Africa, climate change is causing increased temperatures and variability in precipitation, leading to shorter growing seasons in most areas (Adhikari et al. 2015). Temperatures are projected to change even more intensely in the 2050s, 2080s, and 2100s with increases up to four degrees in mean annual temperatures in some locations (Adhikari et al. 2015).

One common strategy for adapting to climate changes is to utilize genetic seed sources to resist abiotic and biotic stressors (IPCC 2014). Rural smallholder farmers in East Africa are vulnerable to climate change and could benefit from the access and exchange of genetic resources, seed, and the information needed to use those resources effectively. East Africa's economies are heavily dependent on agriculture, with at least two thirds of all food production coming from smallholder farmers, making climate change adaptation an essential component of ensuring food security and realizing broader economic development goals (Ombogoh et al. 2016). Agriculture contributes to approximately 30% of Uganda's GDP and 23% of Kenya's GDP, with smallholder farming contributing to roughly 75% of all agricultural production across East Africa (Salami et al. 2010).

Some East African farmers are already adopting climate change adaptation strategies. For example, drought tolerant maize varieties (Fisher & Carr, 2015), improved irrigation systems (Gathungu 2014), companion cropping (Midega et al. 2015) and crop diversification (Deressa et al. 2009, Cairns et al. 2013, Martin et al. 2013) have all shown varying levels of effectiveness at helping farmers sustain or increase crop production. In East Africa, informal seed networks are believed to supply roughly 80% of seeds and seed information to farmers (Louwaars & Noyer 2013). Informal seed networks consist of seed obtained from one's own saved seed, exchanged with neighbors, or seed obtained from local markets. Farmer seed networks are an important element of seed access because they are resilient and work to maintain and conserve crop genetic diversity.

However, heterogeneity across smallholder farms and technical challenges has slowed adoption of potentially beneficial crop varieties and improvement management practices (Fisher & Carr 2015). Preliminary research has suggested that community-generated information-sharing might support more effective farmer response to the changing seasonal and weather patterns associated with climate change (Pringle & Conway 2012). However, little is known about the roles of farmers' social networks in supporting climate change adaption in East Africa. Previous studies have determined that farmer information and seed networks are heavily influenced by demographic factors such as wealth, gender, and religion (Coomes et al. 2015, Tadesse et al. 2016). There remain many important questions surrounding how farmer networks might more effectively support the dissemination of genetic resources and knowledge for climate change adaptation.

Our paper seeks to better understand the factors that influence the ways in which smallholder farmers exchange seed and information. The relationships among farmers in such networks will provide insights into how farmers maintain crop diversity for climate change adaptation; the factors that influence the functioning or malfunctioning of these seed networks and their stability over time. By better understanding the social networks for resource and information exchange, we hope to inform strategies and interventions needed to improve access to genetic diversity for climate change adaptation in these three communities in East Africa.

In order to enhance farmer information networks, the exchange of climate change adaptation information, and the flow of genetic diversity among smallholder farmers in Kenya and Uganda, this study responds to three research questions:

- How are rural farmers in East Africa adapting to climate change?
    - Specifically, what seeds and varieties are they using for climate change adaptation?
- What are the social networks through which farmers exchange seed and information and how stable are these networks?
- How might social networks and information distribution be enhanced to support climate change adaptation strategies in East Africa?

2. Background

2.1 Agricultural Institutions in Kenya and Uganda

Among the many factors influencing smallholder farmer choices in Kenya and Uganda, the most prominent are the major national agricultural institutions and policies in each country. Kenya has three major national entities regarding agricultural and seed related policies (Table 1). The Kenya Ministry of Agriculture, Livestock, and Fisheries's goal is to develop policies and strategies that enable the many stakeholders of the seed industry. The Kenya Plant Health Inspectorate Service registers and certifies seeds, while the Seed Trade Association of Kenya works with national and international seed organizations to facilitate the movement of trade and access (Republic of Kenya Ministry of Agriculture 2010). In Uganda, agricultural policy is largely concentrated in the Ministry of Agriculture, Animal Industry and Fisheries, which implements systems for the diffusion of agricultural information and inputs, and the National Agricultural Research Organization, which provides basic seed through the collaboration of the private sector (Table 2) (Republic of Uganda Ministry of Agriculture, Animal Industry, and Fisheries 2015).

Table 1. Major national agricultural institutions of Kenya.

Institution	Description
Ministry of Agriculture, Livestock, and Fisheries	Develops and coordinates agricultural programs, as well as policies and strategies that promote an accessible environment for stakeholders in the seed industry[1]
Kenya Plant Health Inspectorate Service (KEPHIS)	Responsible for seed variety evaluation, release, and registration; conducts plant variety protection; oversees seed certification; implements national policy for the introduction of genetically modified plant species in Kenya[1]
Seed Trade Association of Kenya (STAK)	Facilitates interaction and information exchange; encourages the development of the national seed industry; works with national and international organizations to aid the Kenyan seed industry; and facilitates the movement of seed through regulatory coordination[1]
Kenya Agricultural & Livestock Research Organization (KALRO)	Conducts agricultural research to influence policy, facility agricultural sustainability, and enhance agricultural technology; directs seed production unit; includes semi-autonomous institutions such as the Genetic Resources Research Institute (GRRI) and Food Crops Research Institute (FCRI) focusing on access and benefit sharing of plant genetic resources[2]
Kenya Seed Company	Acts as a research body and marketer of seed varieties in Kenya and East Africa[3]

[1]Republic of Kenya Ministry of Agriculture 2010; [2]Genetic Resources Research Institute 2016; [3]Kenya Seed Company 2016, [4]Kenya Agricultural & Livestock Research Organization

Table 2. Major national agricultural institutions of Uganda.

Institutions	Description
Ministry of Agriculture, Animal Industry, and Fisheries (MAAIF)	Implements systems to disseminate agricultural information and controls inputs into the agricultural sector[1]
National Agricultural Research Organization (NARO)	Provides basic seed and collaborates with the private sector and farmer groups to work towards development, dissemination, and technology commercialization. Includes the Plant Genetic Resources Center (PGRC), which produces seed and oversees the conservation and governance of agricultural genetic resources in Uganda. PGRC seeds are certified by MAAIF[1, 2]

[1]Republic of Uganda Ministry of Agriculture, Animal Industry, and Fisheries 2015; [2]Plant Genetic Resources Centre 2016

The above institutions appear to be largely disconnected from the informal seed networks upon which many farmers rely (Tables 1 and 2). In Uganda, there are no government programs to support the informal systems of farmer-saved seed, nor is there substantial support for rural farmer entrepreneurs (ISSD Africa 2012). Policies conducted by the Kenyan ministry are similarly focused on the formal seed sector and pay little attention to the important informal systems. When support does exist, its purpose is to formalize the informal systems (Munyi & Jonge 2015). Quality declared seed is an example of a critical seed system, which provides for the informal sector in Uganda and other East African countries (Shiferaw et al. 2008). This community-based seed system allows farmers to label the seed they produce, which is then sold within the farmers' community. The process is overseen by a regulatory agency, lending the system legitimacy (Shiferaw et al. 2008).

In both countries, agricultural extension services, such as the use of mobile phones and other resources to provide demonstrations of new technology (Afranaa-Kwapong et al. 2015), are crucial in the dissemination of information and resources to rural farmers. They are meant to deliver information on patterns in crop prices, seed varieties, and crop management (Muyanga et al. 2006). However, some authors argue that the influence of these services across sub-Saharan Africa may be weak and insufficient (Taye 2013). Extension efforts' efficiency, as well as government policies and institutions, may be improved with a better understanding of farmer networks in Kenya and Uganda. This paper responds to recent calls to support improved extension services delivery (Taye 2013) by examining the characteristics of farmer seed and information networks in Kenya and Uganda.

2.2 Variables Influencing Farmer Networks

There have been many successful studies using network analysis to investigate social seed networks among smallholder farmers in East Africa and the greater Sub-Saharan Africa region (Tadesse et al. 2016, Pautasso 2015, McGuire 2008). Social network analysis documents people or institutions that are connected within a network (Valente et al. 2015). Network analyses are beneficial as they increase knowledge of individual components and interactions that comprise a social network, helping to ensure successful implementation of programs that rely upon such networks (Valente et al. 2015). In the context of social seed networks, network analysis serves as a way to better analyze and comprehend the patterns in the networks farmers use for information about and access to seed (Tadessee et al. 2016). Specifically, network analysis can help understand the socio-economic and biological aspects of seed exchange, encompassing the flow of genes and knowledge within and between communities. These factors influence how farmers determine which particular crop varieties or other adaptation strategies might best support their short- and long-term welfare (Table 3) (Pautasso 2015, Tadessee et al. 2016).

2.2.1 Gender

Gender is a key variable influencing farmer information and seed networks. Women and men may be involved in different crop networks, since women are mostly concerned with food crop production, while men grow cash crops (McOmber et al. 2013). Additionally, men and women often have separate social and agricultural networks, exposing them to different crop information and varieties (Tadesse et al. 2016). Studies have shown that male farmers are more likely to share seeds and information with male farmers, and female farmers share almost equally with male and female farmers (Tadesse et al. 2016). Women have a more dominant role in sharing seeds outside of their community because they often have family ties to the area they grew up in (Tadessee et al. 2016). These network patterns influence the spread of information and genetic resources. Men are more likely than women to adopt climate change adaptation measures (Fisher & Carr 2015). Different gender roles and responsibilities influence opportunities to adopt improved varieties. Female farmers often lack resources such as land, agricultural information, and credit, preventing them from improving technologies (Fisher & Carr 2015, McOmber et al. 2013). While climate change information may enter households, women are not always included in the sharing of this information (Roncoli et al. 2009). Improving women's social networks has been found to help improve yields in some cases (Vasilaky 2012). Since females comprise at least 50% of the agricultural labor force in Eastern Africa (FAO 2011, Vasilaky 2012), improvements in female agriculture-based social networks have the potential to support productivity and livelihoods in this region.

2.2.2 Ethnicity

Ethnicity influences traditional practices in the conservation, utilization and management of genetic resources. For instance, two studies pointed to sorghum as a crop whose distribution among farmers is associated with ethnic groups across the African continent (de Wet et al. 1967, Harlan et al. 1976, Labeyrie 2014), while another based in Mexico found a correlation between ethnolinguistic diversity and genetic crop diversity (Perales et al. 2004). Similar ethnolinguistic groups are more likely to be linked in a seed network (Labeyrie et al. 2016). Alternatively, linguistic boundaries between various ethnic groups can prevent the exchange of seeds and information (Leclerc & Coppens d'Eeckenbrugge 2012). This barrier can result in different varieties of crop among ethnic groups (Labeyrie et al. 2014). Meanwhile, improved varieties of crops may be more uniformly distributed among ethnic groups than across them; in some cases the presence of marriage between different ethnic groups can determine whether or not seed and information exchange occurs (Labeyrie et al. 2014, Labeyrie et al. 2016). The linguistic and cultural barriers between different ethnic groups can limit, or occasionally improve, the exchange of seeds and information (Lebeyrie et al. 2016, Lebeyrie et al. 2014).

2.2.3 Educational Attainment

Past studies looking at the impacts of education on farmer behavior have shown varied outcomes in terms of impact on transfer of seeds and technology, with some positive and some negative associations (Kassie et al. 2011, Thuo et al. 2014). One study looking at pigeonpea varieties in Tanzania revealed that the level of household education is positively correlated with the adoption of improved varieties (Shiferaw et al. 2008). A separate study on groundnuts in rural Uganda found that education leads to greater access to information through membership in "farmer groups" (Kassie et al. 2011). Alternatively, Thuo et al. (2014) found that Kenyan farmers with higher levels of education were less likely to adopt varieties, as they were less sensitive to the decisions made by members of their network.

2.2.4 Access to Information

Access to information and communication technologies may affect transfer of seed through social networks. Greater access to communication technologies has been shown to have a positive effect on seed adoption (Kiiza et al. 2013, McOmber et al. 2013). One study performed in rural Uganda concluded that increased access to technology based information regarding markets and market prices will lead to greater implementation of new and enhanced seed varieties (Kiiza et al. 2013).

2.2.5 Distance to Road Infrastructure & Markets

Distance between farm plots in the network may also influence the exchange of crop varieties in certain areas. Distance between individual farmers has been shown to have a positive association on seed exchange rates, while distance from farmers to larger markets has exhibited a negative association with adopting new seed technology (Pautasso 2015, Kassie et al. 2011). In Uganda, larger distances from markets are found to have a negative impact on the implementation of crops (Kassie et al. 2011). In one study of smallholder barley farmers in Ethiopia, Pautasso (2015) found that the exchange of barley seed usually stayed within small groups of localized farmers, rather than expanding beyond the first round of exchange (Pautasso 2015).

2.2.6 Crop Type

Crop type may also play a role in adoption of information and seed technology. Sorghum is a widely preferred crop in East Africa due to its drought-resistance (McGuire 2008). Millet is another staple crop for many East African countries, particularly for smallholder farmers, due to its resilience in areas prone to drought, heat and poor soil quality (Andrews et al. 1992, Reynolds et al. 2015). These two crops provided a combined 40% of cereal harvested and 23% of total cereal production in 2012 in the greater Sub-Saharan Africa region (FAOSTAT 2013, Reynolds et al. 2015), which suggests a high frequency of passage of these crops through social seed networks. Yet, increasing recognition of the negative impacts that sorghum and millet crops can have on both soil erosion and land degradation on marginal farmland (Reynolds et al. 2015) could affect the use of these crops and their presence in farmer networks. Beans are a vital crop in East Africa as they are harvested as a food source for farming families as well as a cash crop for commercial markets (David & Sperling 1999). For example, in Uganda and the Great Lakes region, beans contribute to 65% of people’s protein (David & Sperling 1999). However, there is evidence that bean exchange has been inhibited by weak social ties that may exist in farmer networks (David & Sperling 1999).

2.2.7 Organization Involvement

Different types of organizations, such as farmers’ groups, banking groups, women’s groups, help and support groups, youth groups, table banking and financial groups, non-profits and environmental groups can influence the exchange of seed varieties and climate adaptation information. For example, Climate Change, Agriculture and Food Security (CCAFS) is a research program under the Consultative Group on International Agricutural Research (CGIAR), that provides capacity enhancement and tools for farmers in East Africa and other regions (CCAFS 2016). Another example is Friends of Katuk Odeyo (FOKO) in Kenya, which is a community-based organization that works to address the challenges posed by climate change and poverty (CGIAR 2013). Ugandan farmers associate with far fewer organizations, with table banking groups being the only prominent organization for both male and female farmers, as access to capital for agriculture has been a hindrance to smallholder farmers in East Africa (Kirui et al. 2010).

Table 3. Variables influencing farmer networks.

Variables	Reasoning	Support
Gender	Men and women have different social networks, which may influence the exchange of and access to varieties and information. Women's social networks are primarily made up of other women. Women are less likely to receive climate change adaptation information through their network.	Tadesse et al. 2016; Fisher & Carr 2015; McOmber et al. 2013; Vasilaky 2012; Roncoli et al. 2009
Ethnicity	Linguistic boundaries between ethnic groups can limit the exchange of seeds and information.	Labeyrie et al. 2016; Labeyrie et al. 2014; Leclerc & Coppens d'Eeckenbrugge 2012
Education	Higher and lower levels of education may lead to positive association with access to information and seed technologies.	Kassie et al. 2011; Shiferaw et al. 2008
Seed and Information Exchange	Increased access to information and communication technologies lead to a positive association with access to information and seed technologies.	Kiiza et al. 2013
Distance	Larger distances to markets have a negative association with crop implementation. Farmers in close proximity to each other are more likely to share seeds.	Pautasso 2015; Kassie et al. 2011
Crop	Demand for seed and distance between farmers impacts the type and frequency of seed dispersal. Bean exchange is influenced by weak social ties between farmers.	Pautasso 2015; McOmber et al. 2013; David and Sperling 1999; McGuire 2008
Organization Involvement	Involvement in agricultural organizations or farmer groups enhances the exchange of information and access to agricultural services.	Bratton 1986

3. Methods

To better understand farmers' primary sources of information, we analyze original survey data collected by Bioversity International in July through September of 2016, including 364 household surveys from Nyando District in Kenya and 301 household surveys from Hoima District in Uganda (Figure 1). Surveys collected various farm-level data on crops grown, access to tools and assets, sources of seeds and seed exchange networks, sources of expert information, and relationships between information sources.

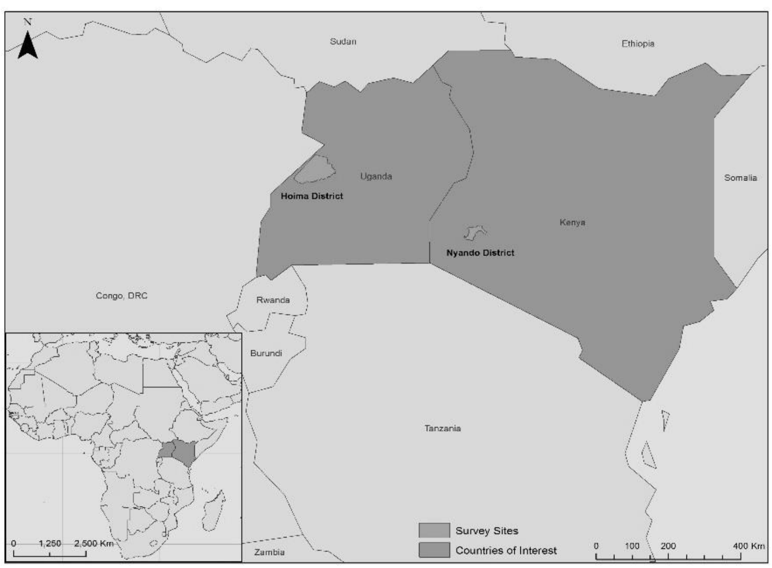

Figure 1. Survey sites in Kenya and Uganda.

Following established methods drawn from a review of existing literature, we use UCINET software to conduct a social seed network analysis (Abay et al. 2011, Pautasso et al. 2013, Rufino et al. 2009, Thuo et al. 2013), illustrating how climate change adaptation information is transmitted through farmer information networks and how seed is accessed and exchanged among smallholders in the three communities. Finally, we consider how targeting specific types of information to specific information sources might support improvements in smallholder adaptation and ultimately improved farmer welfare.

3.1 Description of the Sample

For both Kenya and Uganda, 60% of respondents were women and 40% were men. Three tribes were identified by respondents in Kenya. The majority were Luo and Kalenjin, making up 48% and 39% of the surveyed population respectively. Kipsigis was the tribe identified by 13% of the population. The respondents in Uganda identified with a greater number of tribes, including Bunyoro, Ankole, Buganda, Kabajunga, Lugbara, Luo, Mugugu, and Mukiga. However, 94% of the surveyed population identified as Bunyoro.

Overall, 55% of surveyed farmers in both Kenya and Uganda have completed primary school or had some secondary schooling, while 14% have received no education at all. In Kenya, there were some differences in educational attainment by gender, with slightly more women having no education than men.

Distance to market for Kenyan farmers is approximately 9 km from respondent households on average. There were differences depending on tribe, however. In Kenya, for the Kalenjin tribe, the average distance is 12 km while the distance for the Luo tribe is 9 km, and for the Kipsigis tribe the distance is only 2 km. In Uganda the average distance to market is 4.25 km, with no differences across tribe. Distance to the nearest surrounding town was also evaluated; Kenyans in the Kalenjin tribe are found to be approximately 26 km from the nearest town, Luo tribe members were 24 km, and Kipsigis tribe members were 13 km away. The average distance for all Ugandan respondents is 16.3 km. In terms of nearest major all-weather road Kenya farmers in the Kalenjin tribe are 4.7 km away, while Luo farmers are 3 km and Kipsigis farmers are 1.3 km. For Ugandan respondents, farmers are on average 2.6 km away from the nearest major all-weather road.

For farmers surveyed in Kenya, the most common crops grown were maize, sweet potato, sorghum, and cowpea (Figure 2a). In Uganda, the most common crops for surveyed farmers were maize, sweet potato, and cassava (Figure 2b). There are few differences between crops grown for males and females across both countries. Overall, a higher percentage of farmers surveyed in Uganda use individual crop varieties than those in Kenya.

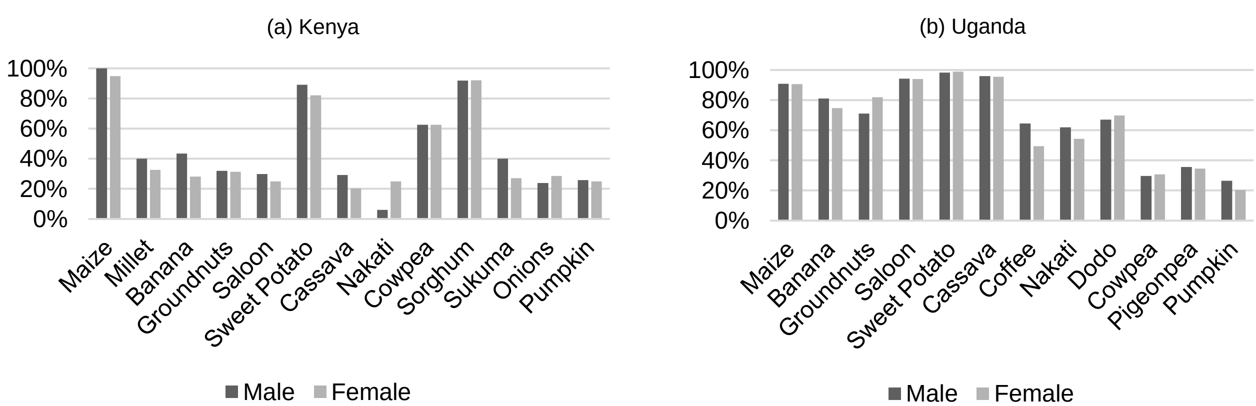

Figure 2. Most common crops grown by gender for Kenya (a) and Uganda (b).

Farmers were asked which resources contribute to their household income, including farming tools or assets and off-farm jobs. The most common tools or assets owned in the past year were machete, hoe, mobile telephone, radio, and axe (Figure 3). A greater percentage of women surveyed owned each of these assets. Off-farm sources of income were occurring for 41% and 47% of Kenyan and Ugandan respondents, respectively. The majority of these activities are from petty trading, handcrafts, casual labor, and boda-boda (motorcycle taxi) for both Kenya and Uganda (Figure 4). However, salaried employment, remittance, and other activities appear to play a larger role in Ugandan off-farm sources of income (Figure 4b). A greater percentage of surveyed men in both Kenya and Uganda obtained off-farm income from boda-boda, casual labor, and salaried employment.

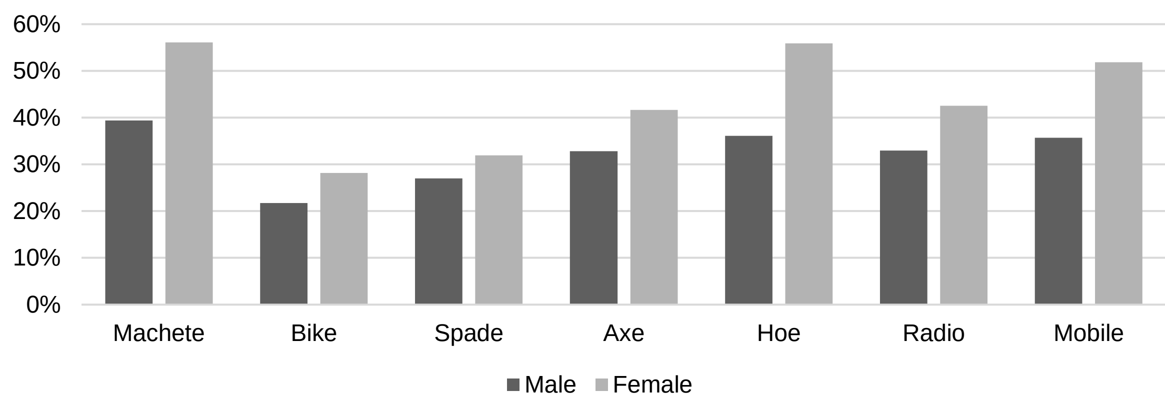

Figure 3. Most commonly owned farm assets by gender in both Kenya and Uganda.

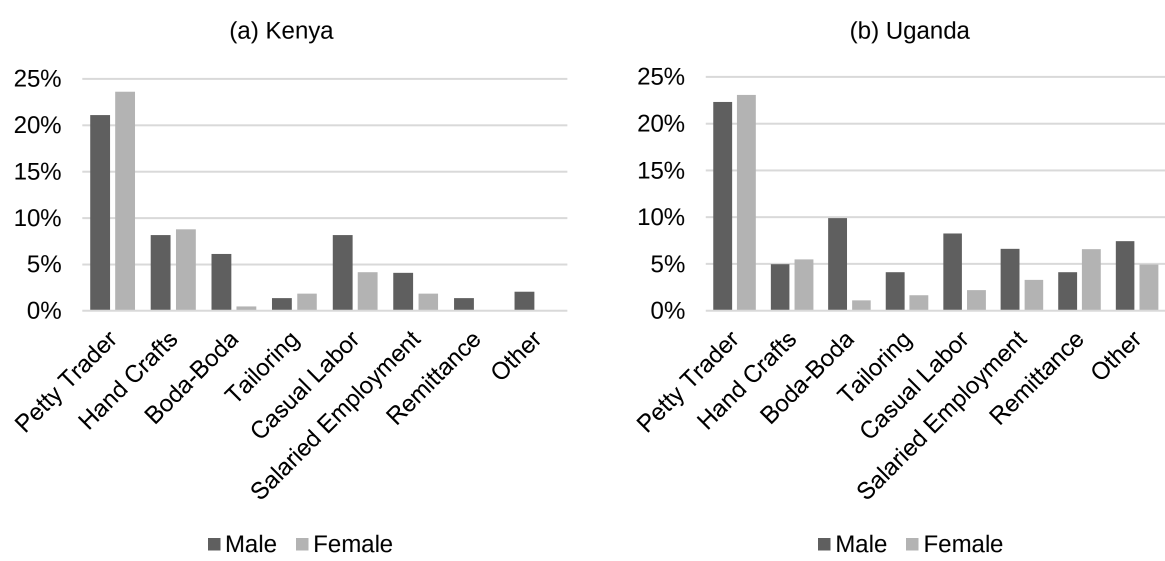

Figure 4. Involvement of surveyed farmers in specific off-farm activities in Kenya (a) and Uganda (b).

3.2 Methods of UCINET analysis

In our network analysis, we perform density, centrality, and betweenness calculations. Calculating density in a network shows the overall level of connection within a network. It is a calculation of the total number of ties divided by the possible number of ties in a network. Centrality is a measure of how well connected an actor is to the overall network. It produces in-degree (the number of connections received) and out-degree (the number of connections sent out) values that show an individual's influence in the network. Betweenness analyzes the extent to which an actor falls on the geodesic path between other pairs of actors in the network. This actor is viewed as a mediator of information or a liaison for resource flows. The normalized mean of betweenness resets the scale. Instead of treating every connection as one, the normalized mean accounts for connections as a fraction of the total number of connections. This means that if the entire network was connected, the normalized mean would have a value of one.

4. Results

4.1 Seed and Information Sources for Climate Change Adaptation

4.1.1 Seed and Information Exchange

A variety of survey questions were related to whether the exchange of seeds and information was present and how these resources were distributed. Approximately 35% of Kenyan respondents and 25% of Ugandan respondents indicated that they discuss seed varieties with someone. Farmers were asked whether they used other sources to obtain information on seeds. Trends for sources of information were similar for both Kenya and Uganda, though Uganda has an overall higher use of each source (Figure 5). The most common sources from which respondents obtain seed information were field days, agricultural shows, radio talks, and seed events.

Farmers were also asked who they provide seeds to and obtain seeds from. About 30% of both Kenyan and Ugandan farmers supplied seeds to a farmer within their own village. About 10% of respondents in Kenya and Uganda supplied seeds to a farmer outside their own village. Main seed sources differed between Kenya and Uganda. Respondents in Kenya relied on a greater number of resources, including their own seed, neighbors, local markets, seed companies, and farmer groups (Figure 6a). In Uganda, the main seed sources for respondents were their own seed, neighbor, or local market (Figure 6b). For both countries, farmers' own seed was ranked the most important seed source.

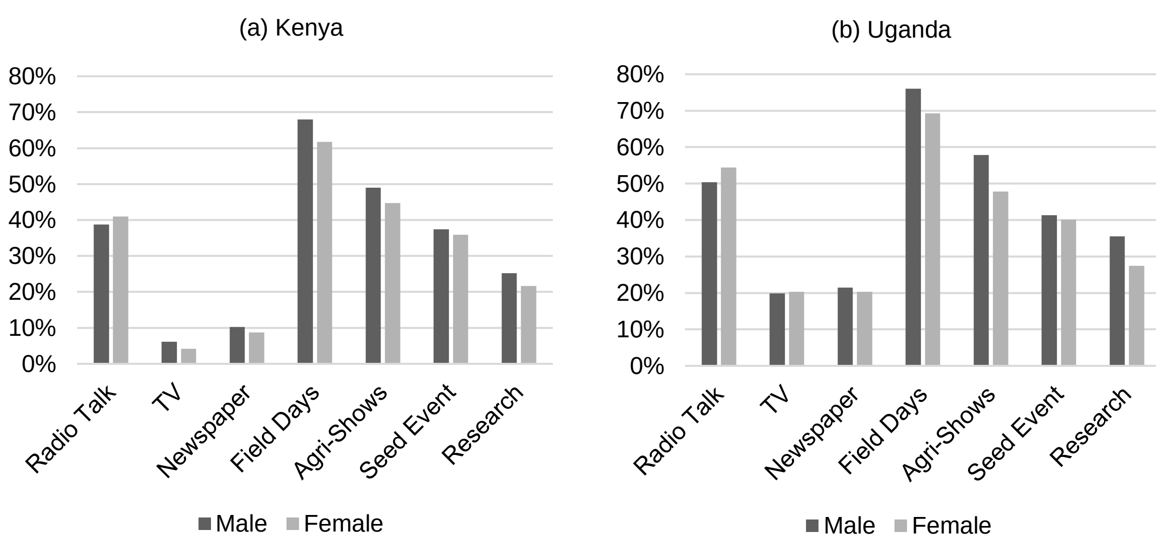

Figure 5. Other Sources of seed information in Kenya (a) and Uganda (b).

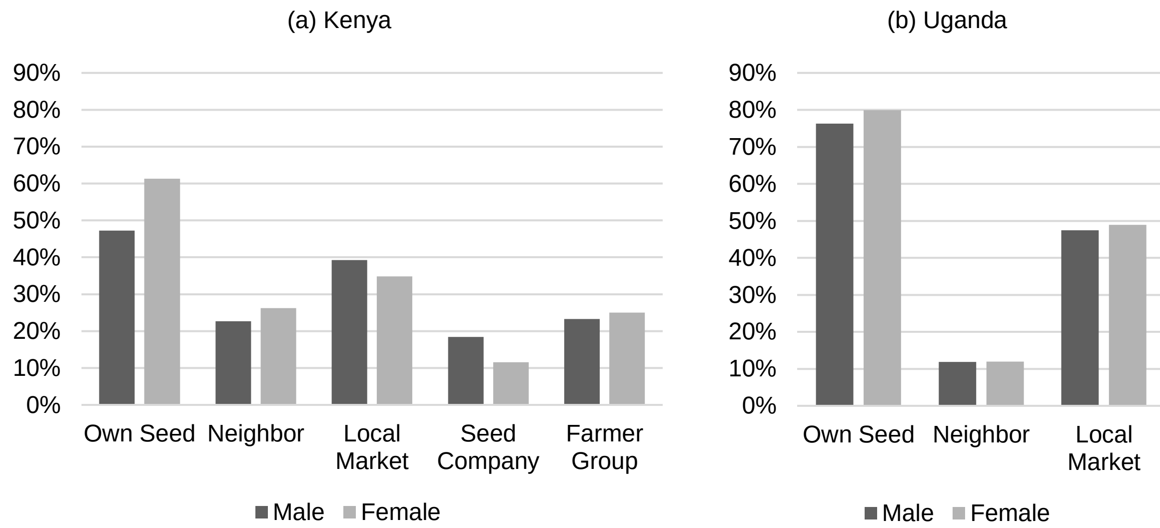

Figure 6. Main seed sources in Kenya (a) and Uganda (b).

Kenyan respondents were also analyzed by tribe. The most common seed sources for the Kalenjin tribe were their own seed and seed companies (Figure 7). For the Kipsigis tribe, the most common seed sources were farmer groups and the local market. Lastly, the Luo tribe's most common seed sources were their own seed and the local market. Additionally, extension services played little to no role in seed sources for Kenyan and Ugandan farmers.

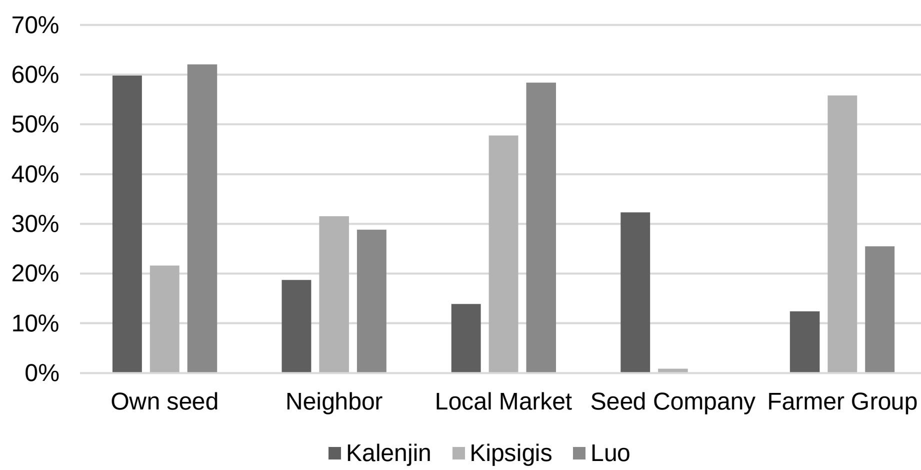

Figure 7. Main seed sources by tribe in Kenya.

4.1.2 Organization Involvement in Seed Provision

Farmers were asked whether they had been actively involved in any local farm-related organization over the last three years. Overall, 55% of surveyed Kenyan farmers and 45% of surveyed Ugandan farmers were involved in an organization. In Kenya, surveyed farmers were involved in an organization for 50% of the Kalenjin tribe, 73% of the Kipsigis tribe, and 54% of the Luo tribe. In Uganda, 46% of the Bunyoro tribe were involved. When analyzed by education, the majority of surveyed farmers in Kenya who had basic education or had completed primary school were more involved in an organization (Figure 10). In Uganda, the majority of those with no education, basic education, and completed primary school were not involved in an organization, while the majority of those with some secondary schooling were involved in an organization.

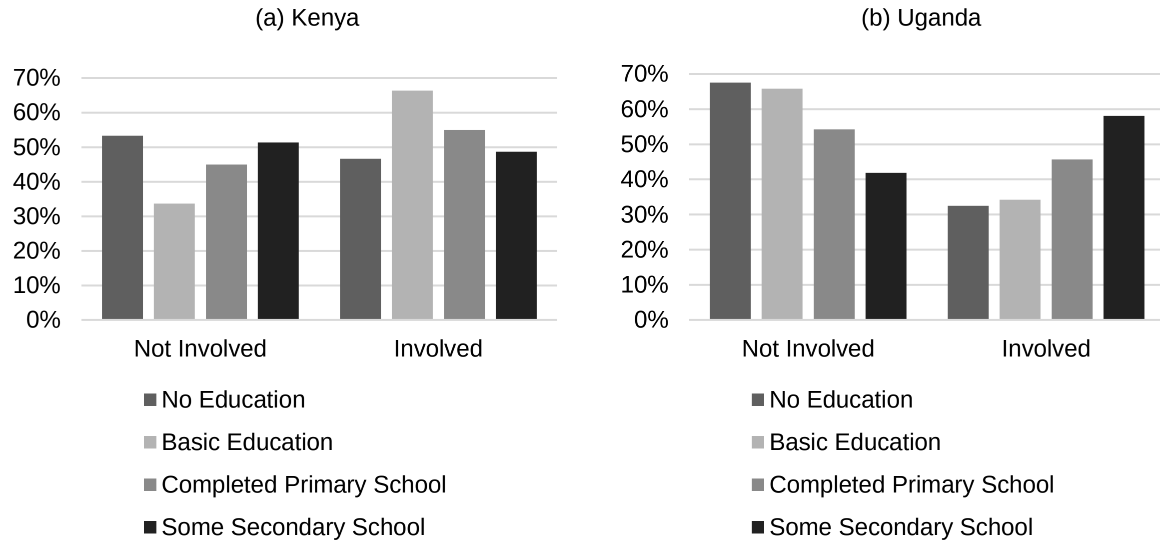

Figure 8. Involvement in an organization by education level in Kenya (a) and Uganda (b).

Table 4. The most common experts to discuss seed varieties and their corresponding organization, as indicated by Kenyan and Ugandan respondents.

	Expert	Men	Women	Total
Kenya	W Nindo (CCAFS)	42	69	111
	S Matinde (FOKO)	22	11	33
	C (WORLD NEIGHBORS)	7	14	21
	E Ouko (FOKO)	9	8	17
Uganda	J Masanyu (BULINDI ZARDI and NARO)	4	12	16

4.1.3 Climate Change

More than 90% of respondents from both countries claiming they have experienced climate related challenges. Yet, a very small portion of respondents utilize distinct seed varieties meant for adapting to climate change, such as drought tolerant varieties, though utilizing genetic resources to resist climate change stressors has been recommended as a successful strategy to combatting climate-induced challenges (IPCC 2014).

The high red sorghum and *mwezi mbili* (a variety of sorghum) adoption among farmers in Kenya demonstrates that farmers are trying to use genetic diversity to adapt, since both of these crops are naturally drought tolerant. This adoption once again highlights the weak relationship between the formal and informal seed systems in these regions. Both of these crops are drought-tolerant but are not "improved," suggesting that farmers may not have access to formal systems which would be the groups providing farmers with improved varieties.

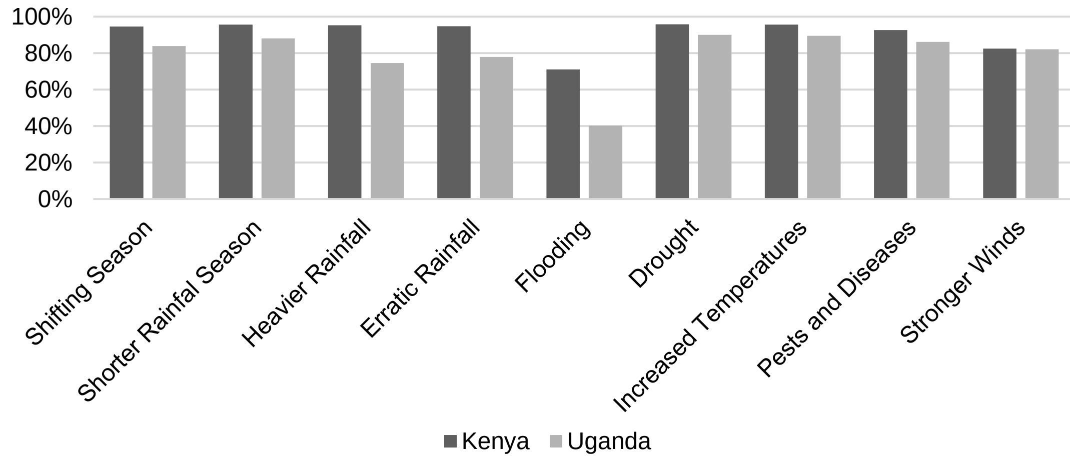

Figure 9. Specific climate related challenges as indicated by Kenyan and Ugandan

Table 5. Percentage of specific varieties used by respondents who use seeds to cope with climate change for Kenya and Uganda.

Kenya		**Uganda**	
Red sorghum	31%	Seed engufu	80%
Mwezi mbili	30%	Kaita bahuru	9%
Andiwo	11%	White beans	8%
Kat B9	8%	Seed endaira	5%
Rose cocoa	7%	Black beans	4%
Kajimbo riat	6%	Brown millet	4%
Seredo	6%	Bukalasa	1%
Ochuti	6%	Red beans	1%
Nyayo	5%	Makerere	1%
Nyakamusa	4%		

4.2 Network Analysis

Figures 10a, 10b, 11a and 11b provide a visual representation of the different organizations that respondents listed. These include farmer groups, women's groups, youth groups, environmental groups, support and self-help groups, financial groups, and agricultural extension services. Some farmers only provide one organization, but others are connected to multiple groups. The network analysis of the groups that males are involved with show that these groups have a higher density than the female groups. The Ugandan organization analysis has a higher density than the Kenyan one.

Figures 12a, 12b, 13a, and 13b show the seed sharing network of respondents divided by gender and country. Respondents were asked who they obtained seeds from and gave seeds to, inside of and outside of their village. The male and female networks within Kenya have more actors than the Ugandan ones and display more complex connections. Tables 8a and 8b show that all of the Kenyan networks have higher mean centralities. Additionally, the Kenyan networks have higher betweenness than the Ugandan counterpart.

Looking specifically at subsites in Kenya and Uganda, all of the Kenyan subsites rank higher than the Ugandan subsite except for Kisumu (Table 6). Sigowet scored the highest of all of the subsites, and looks visually more connected and complex then the Ugandan site (Figures 16a and 16b).

In Kenya, sorghum and bean farmers had the highest network centralities, followed by millet (Table 9a). In Uganda, bean farmers had the highest centrality, followed by millet and sorghum (Table 9b). Kenyan farmers have higher centralities than their Ugandan counterparts, and Kenya's crop networks have higher betweenness as well.

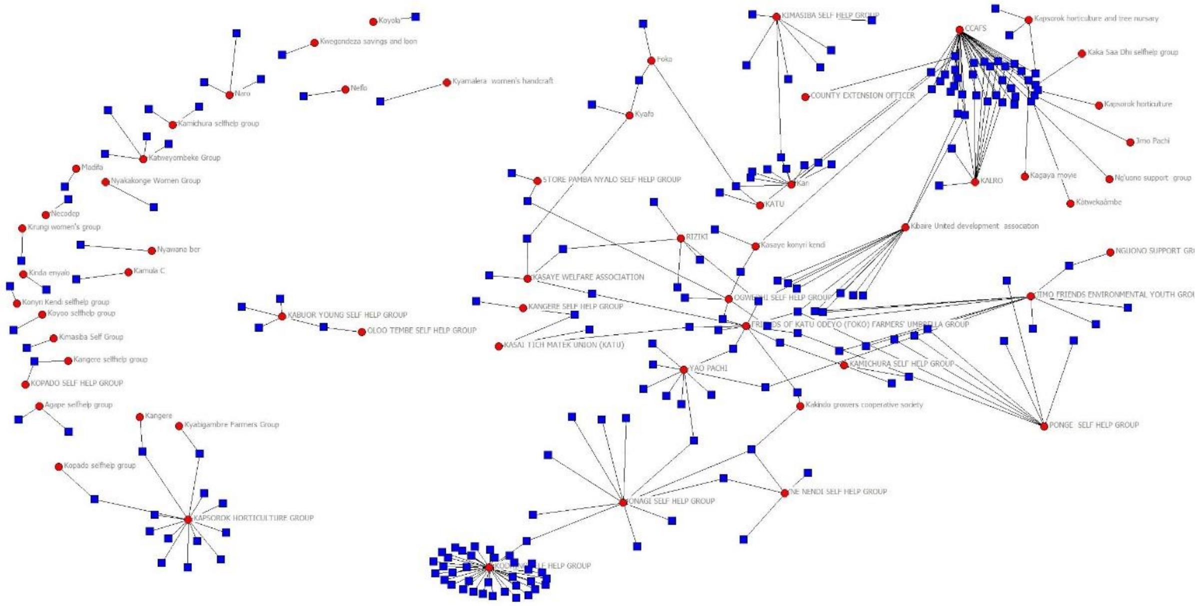

Figure 10a. Displays connections between individual male farmers and organizations in Kenya. Red circles represent organizations; blue squares represent male farmers. The density of this network is 5.0%.

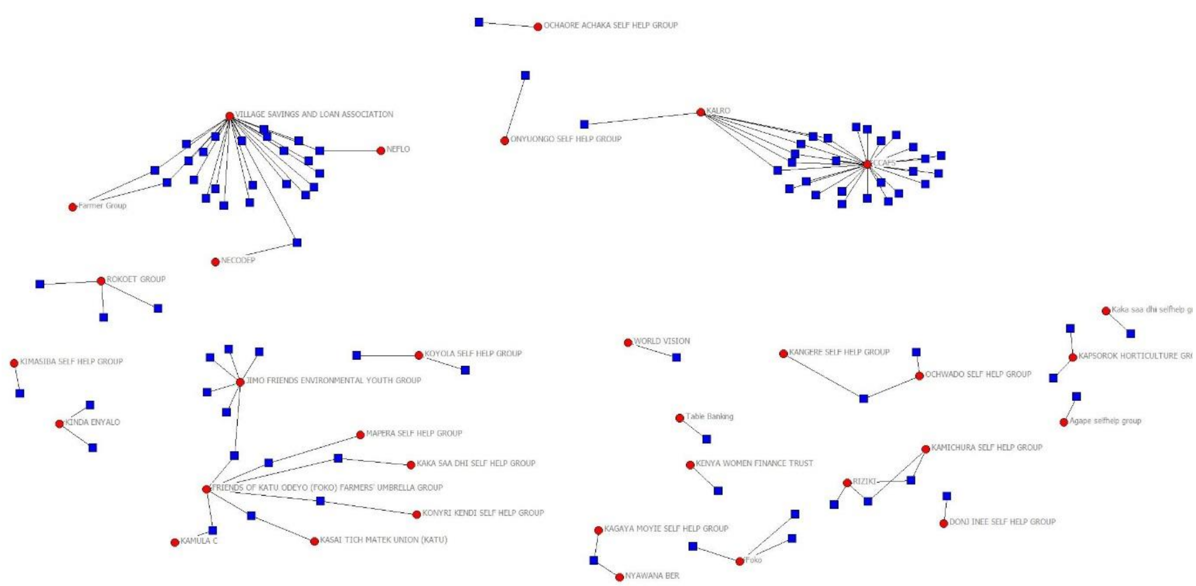

Figure 10b. Displays connections between individual female farmers and organizations in Kenya. Red circles represent organizations; blue squares represent female farmers. The density of this network is 3.6%.

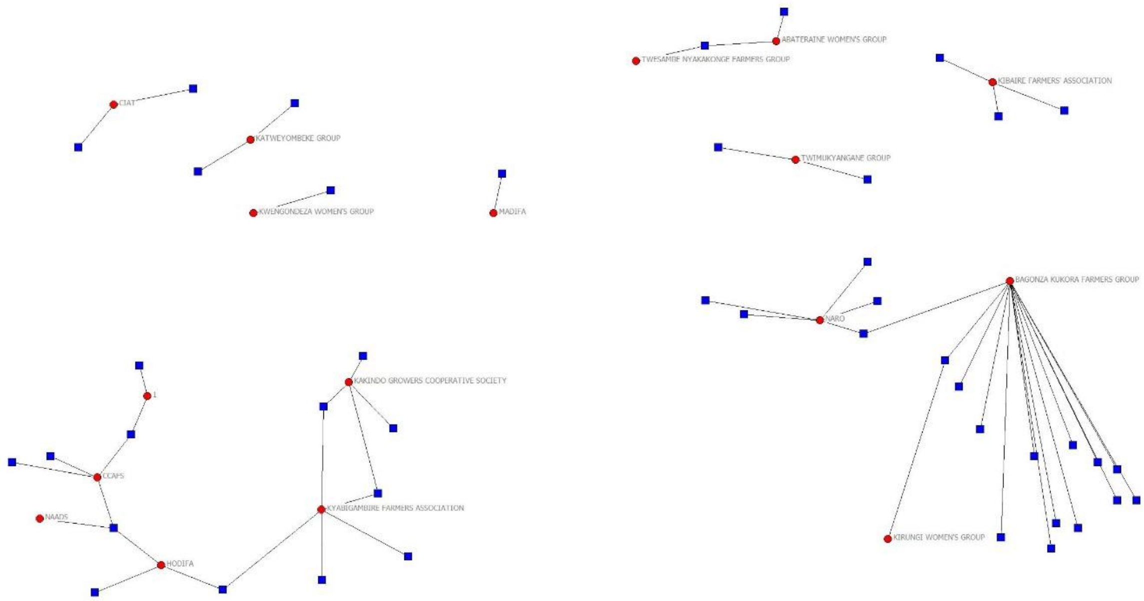

Figure 11a. Displays connections between individual male farmers and organizations in Uganda.
Red circles represent organizations; blue squares represent male farmers. The density of this network is 7.1%.

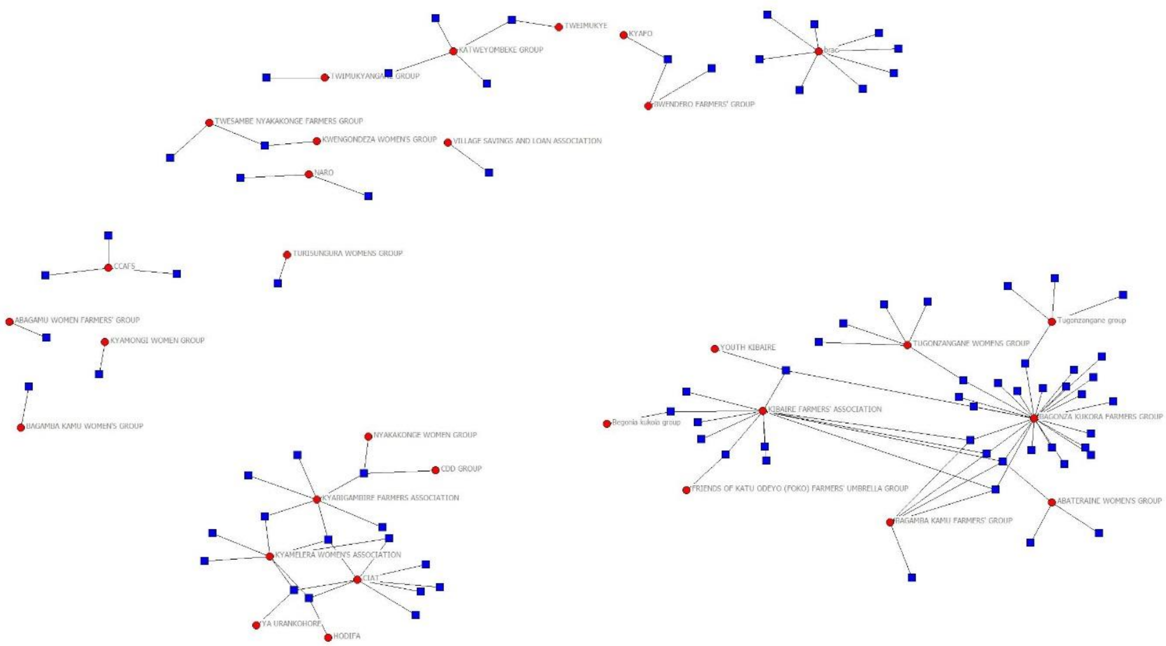

Figure 11b. Displays connections between individual female farmers and organizations in Uganda.
Red circles represent organizations; blue squares represent female farmers. The density of this network is 4.3%.

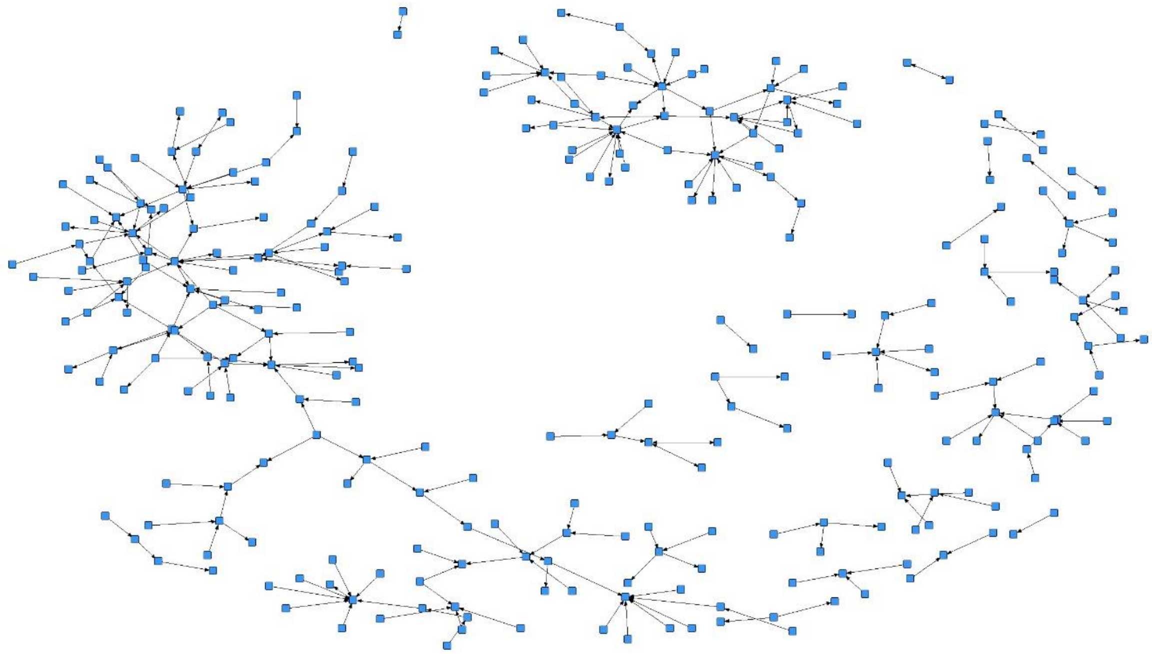

Figure 12a. Network of seed exchange among male farmers in Kenya.

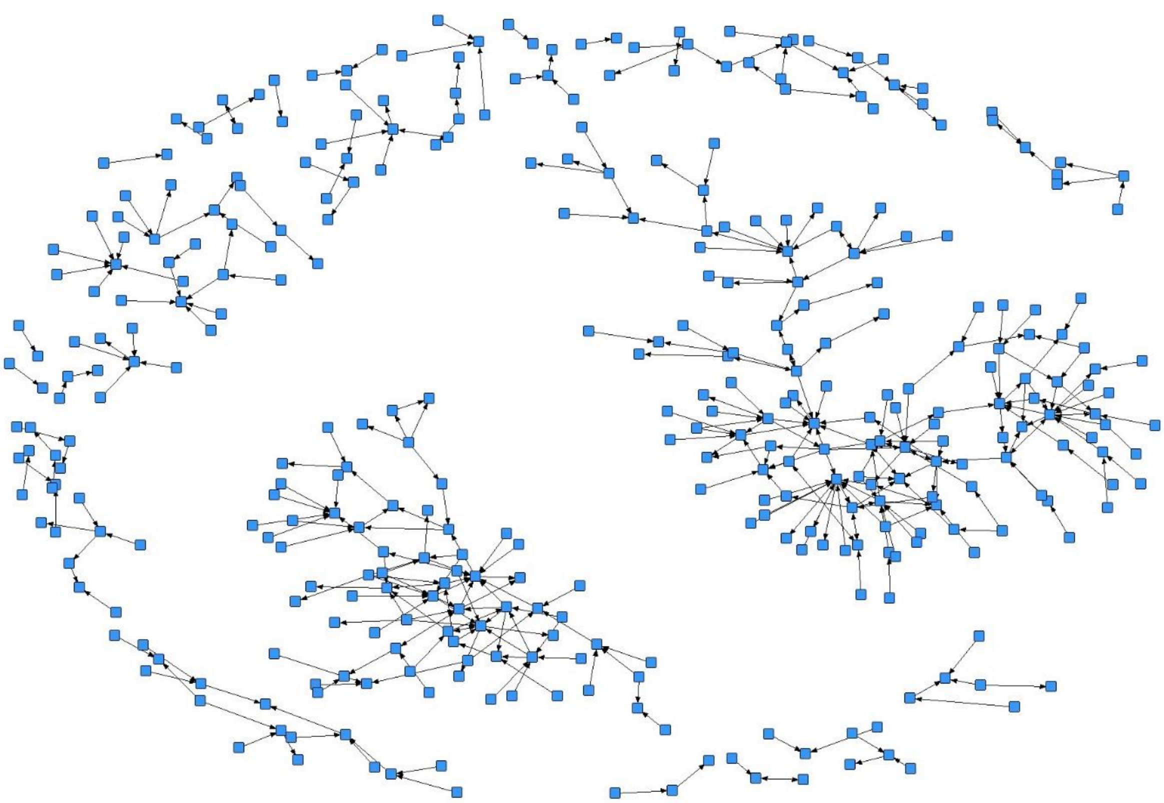

Figure 12b. Network of seed exchange among female farmers in Kenya.

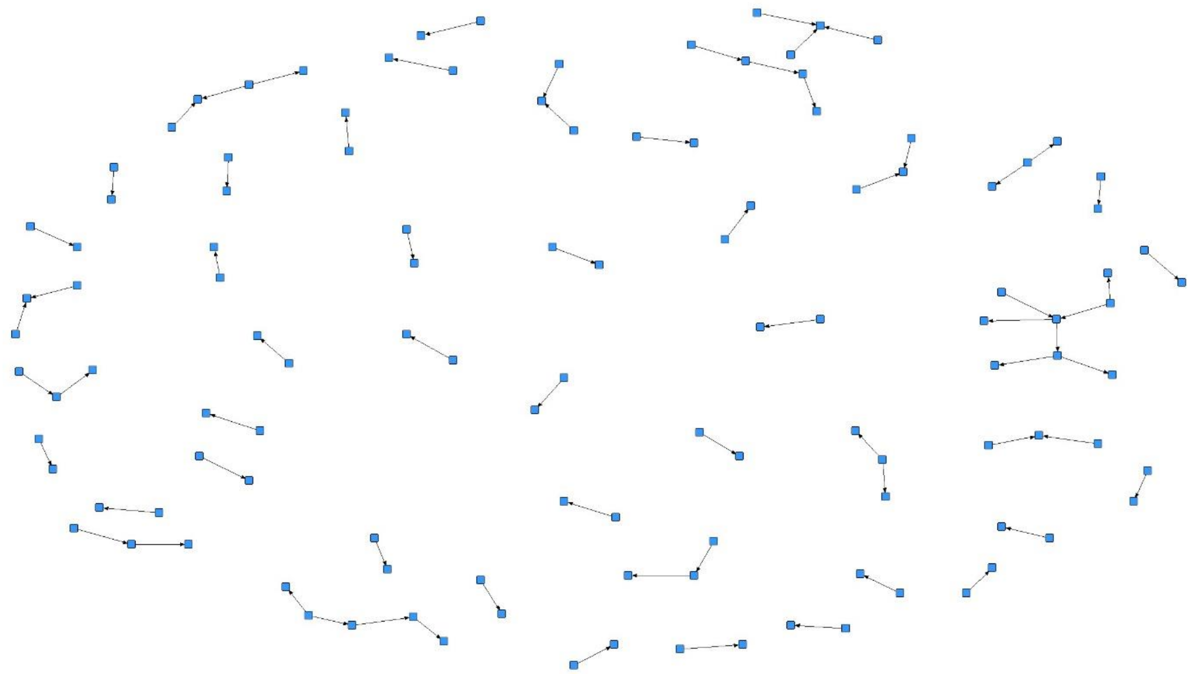

Figure 13a. Network of seed exchange among male farmers in Uganda.

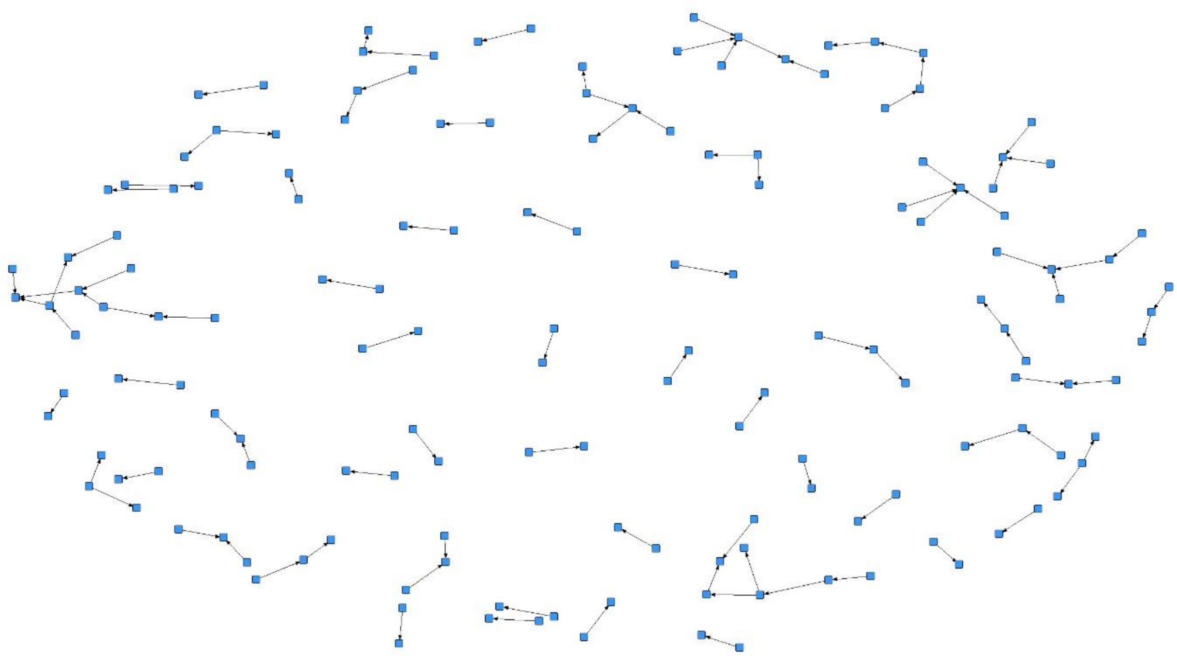

Figure 13b. Network of seed exchange among female farmers in Uganda.

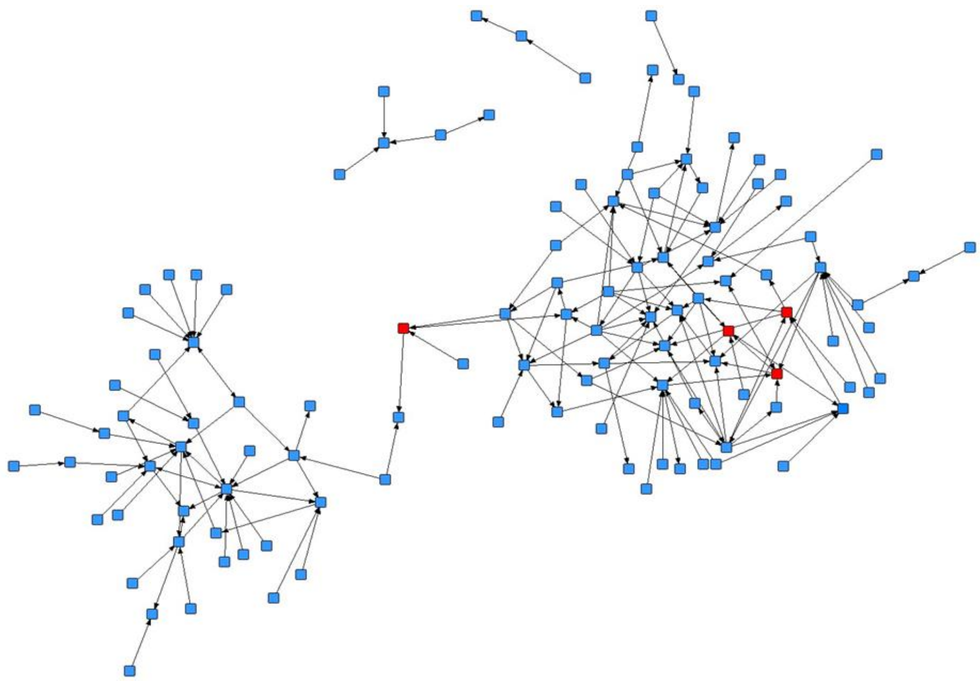

Figure 14a. Farmer connections in Kenyan subsite, Sigowet. The total mean betweenness of the network is 43.368, and the normalized mean of the network is 0.352.

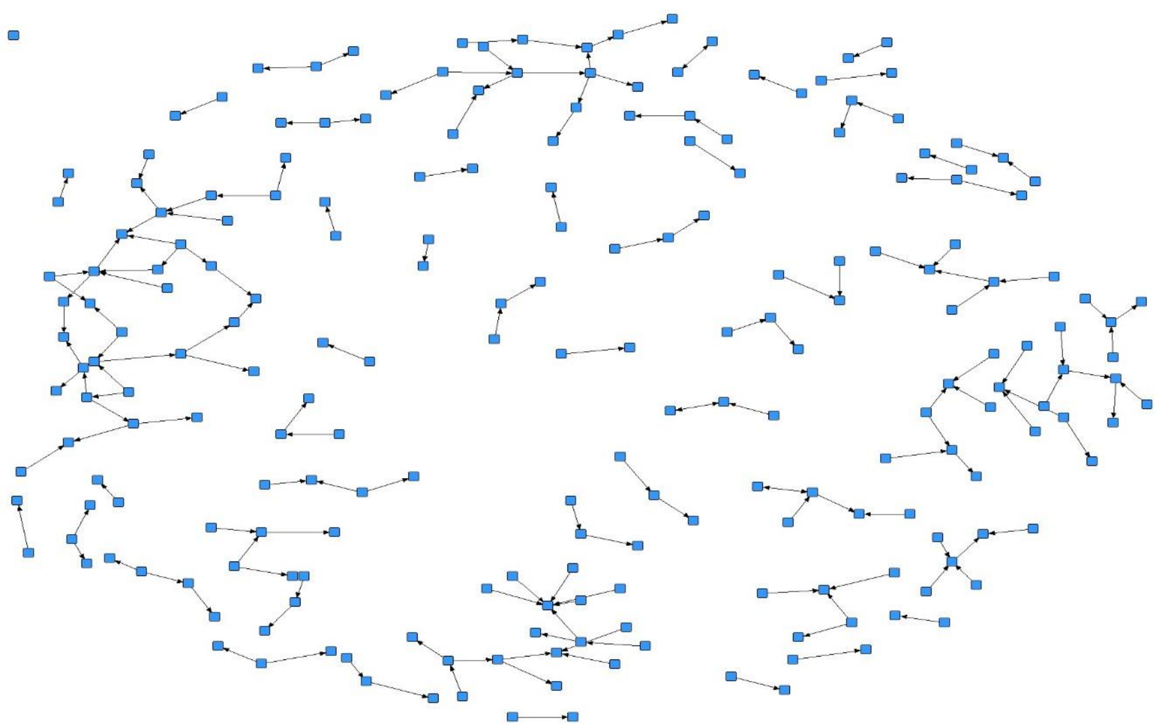

Figure 14b. Farmer connections in Ugandan subsite, Kyabigambire. The total mean betweenness of the network is 0.778, and the normalized mean of the network is 0.02.

Table 8a. Summary of network analysis statistics of seed exchange for Kenya.

	Density	Centrality			Betweenness		
		Outdegree	Indegree	Mean	Total Mean	Normalized Mean	Network Centralization Index
Total	0.005	1.22%	1.76%	1.158	62.422	0.02	0.63%
Men	0.003	1.78%	2.49%	0.958	4.316	0.005	0.12%
Women	0.003	1.36%	2.19%	1.006	30.275	0.023	0.61%

Table 8b. Summary of network analysis statistics of seed exchange for Uganda.

	Density	Centrality			Betweenness		
		Outdegree	Indegree	Mean	Total Mean	Normalized Mean	Network Centralization Index
Total	0.004	1.04%	2.44%	0.773	0.778	0.02	0.04%
Men	0.005	1.22%	2.09%	0.598	0.214	0.002	0.06%
Women	0.004	0.89%	2.20%	0.649	0.26	0.001	0.02%

Table 9a. Summary of network analysis statistics of seed exchange by crop type in Kenya.

	Density	Centrality			Betweenness		
		Outdegree	Indegree	Mean	Total Mean	Normalized Mean	Network Centralization Index
Beans (n=195)	0.004	0.67%	2.74%	0.708	0.467	0.001	0.02%
Millet (n=96)	0.006	1.51%	1.51%	0.583	0.063	0.001	0.04%
Sorghum (n=195)	0.004	1.17%	2.21%	0.733	0.497	0.001	0.03%

Table 9b. Summary of network analysis statistics of seed exchange by crop type in Uganda.

	Density	Centrality			Betweenness		
		Outdegree	Indegree	Mean	Total Mean	Normalized Mean	Network Centralization Index
Beans (n=167)	0.004	1.40%	2.01%	0.689	0.641	0.002	0.06%
Millet (n=44)	0.013	1.08%	3.46%	0.545	0.136	0.008	0.11%
Sorghum (n=5)	0.100	18.75%	18.75%	0.400	-	-	-

Table 10. Network analysis for subsites in Kenya and Uganda based on seeds exchanged within a respondent's subsite.

	Subsite	Density	Centrality		Betweenness			
			Outdegree	Indegree	Mean	Total Mean	Normalized Mean	Network Centralization Index
Kenya	Kericho (n=143)	0.007	2.87%	4.29%	0.951	4.294	0.021	0.41%
	Kisumu (n=126)	0.007	0.93%	6.58%	0.841	0.714	0.005	0.06%
	Nyakach (n=91)	0.013	3.19%	8.80%	1.165	13.385	0.167	2.22%
	Sigowet (n=117)	0.012	4.85%	5.72%	1.427	43.368	0.325	2.89%
Uganda	Kyabigambire (n=216)	0.004	1.04%	2.44%	0.773	0.778	0.02	0.04%

5. Discussion

Social seed network analysis allows for greater understanding of socioeconomic and biological factors that influence the exchange of information and assets (Pautasso 2015). Examining these networks in the context of our project helps enhance understanding of farmer interactions in East Africa, highlighting how farmers gain climate change knowledge and access seed (Tadesse et al. 2016). We have shown this by investigating networks of Kenyan and Ugandan farmers based on various demographic variables, where we are able to determine which currently established networks have been most successful at exchanging seed and genetic diversity and increasing farmer access to climate-adapted varieties.

5.1 Crop Diversity across Study Area

Our analysis showed that farmers have different crop preferences than the current literature implies. Sorghum is among the most commonly used crops among Kenyan respondents. However, sorghum is not among the top twelve crops grown by Ugandan respondents, despite the fact that much of the literature addressed sorghum and millet as key drought resistant crops utilized by farmers in combatting climate change (McGuire 2008, Reynolds 2015). Additionally, our initial research pointed to beans as a highly utilized source of protein and an important cash crop in commercial markets, which would likely cause farmers to utilize beans as a staple crop; however, our results show fewer farmers prefer using beans compared to other popular crops. This could support hypotheses claiming that social relationships can constrain bean exchanges between farmers (David & Sperling 1999). The focus of many articles we explored remained on maize (Cairns et al. 2013, Fisher et al. 2015), and sorghum (McGuire 2008, Martin et al. 2013, Labeyrie et al. 2016, Labeyrie et al. 2014), but our results illustrate that farmers have a much wider array of crops, which they rely upon. Ugandan farmers' crop preferences are much more uniform, whereas in Kenya, farmers exhibit a clear preference for maize, sweet potato and sorghum.

The survey results provided contradictory evidence with much of the literature surrounding relationships between crop varieties used and gender. Men were predicted to be more likely to grow cash crops such as bean varieties, specifically cowpea and pigeonpea, yet our data show a more even gender distribution than expected for these bean varieties (Figure 3).

5.2 Assets and Off-Farm Sources of Income

Our analysis showed that a higher percentage of women own agricultural assets than men. This contradicts the common assumption that men have a higher number of agricultural inputs than women (Peterman, Behrman, & Quisumbing 2014). Farmers appear to have a variety of off-farm sources of income. This may be due to the necessity for more income due to adverse climate change effects on agricultural productivity (Adhikari et al. 2015).

5.3 Organizational Involvement

Although summary statistics show that Kenya had a slightly higher percentage of respondents involved in organizations, there are also more organizations named by Kenyans than Ugandans. This could be due to a greater number of organizations present in Kenya, or that Kenyan organizations are recruiting more members. There are also more experts involved in organizations listed in Kenya than Uganda, likely due to the higher number of Kenyan organizations listed. Looking at the network analysis, there are differing network densities between Kenyan and Ugandan organization networks. Density shows the overall level of connection within a network and is calculated by using the sum of all ties divided by all possible ties. Since fewer organizations were named by Ugandan respondents, it is expected that the network analysis of males and females involved in organizations in Uganda would be denser because there are fewer possible ties. Specifically, though more Kenyan respondents are involved in organizations (male density: 5%, female density: 3.6%), they are involved in many different organizations compared to the Ugandan respondents (male density: 7.1%, female density: 4.3%), resulting in a lower network density.

Althoughthere is a fairly even split between farmers involved in an organization in Kenya and Uganda, more patterns emerge when involvement is compared with educational attainment. In both countries, no completion of education is associated with a lack of involvement in an organization. In Kenya, basic education and completion of primary school leads to greater involvement. These two findings may be a result of the skills and values obtained through educational attainment that make people more likely to involve themselves in an organization (Tang 2008). In Uganda, the reverse occurs. Those who have completed basic education and primary school are more involved. This may be due to educated farmers having more confidence in their own knowledge and lacking motivation to engage in other sources of information provided by organization involvement (Thuo et al. 2014).

5.4 Seed and Information Exchange

Our analysis reflects the lack of institutional focus on informal seed systems in East Africa. The lack of government programs for informal systems and the emphasis on private and formalized systems clearly affects how farmers obtain seeds and information (ISSD Africa 2012). The high reliance on farmers' own seed and local markets may also be indicative of a lack of institutional focus on informal systems. When support does exist, it is manifested in private systems which are largely absent in our analyses (Munyi & Jonge 2015). Kenyan respondents named farmer groups as a source of seeds, while Ugandan respondents did not include this as a source. Our analysis therefore demonstrates that farmers heavily rely on their own resources and those of their local and informal systems to obtain seeds.

Extension services played a miniscule role in the importance of seed sources across all demographic variables for both Kenya and Uganda, with only six people in the entire survey indicating that extension services were a source of seed. Though the intended purpose of extension services is to deliver seed varieties and information, it appears that this service is insufficient and is not reaching the intended audience (Muyanga et al. 2006). The surveyed populations in Kenya and Uganda emphasize the potential for improvement in the system.

In terms of network analysis, female networks are stronger than male ones in both countries. This fits with our earlier hypothesis that women would have larger networks as they often retain ties in their old villages yet also create new relationships after they are married in new villages (McOmber et al. 2013).

The gender networks in Kenya have much higher mean centralities than the ones in Uganda, indicating that there are more connections being made in these networks. This network analysis data also showed that women are more likely than men to receive second-hand information. The higher betweenness values in female networks indicate that more people are connecting actors together creating longer chains of seed exchange. This data shows that women are more likely to receive information that has been passed through many other women than men are.

The three crops that were analyzed with UCINET software were beans, millet, and sorghum. In Kenya, the network of sorghum farmers had the highest mean centrality, meaning it had the highest amount of connections. Sorghum is one of the most commonly grown crops among respondents in Kenya (Figure 3), so this network should have the most connections since many respondents are sorghum farmers. Similarly, the bean farmers in Uganda had the highest mean centrality of the crop networks, which is expected since millet and sorghum are not widely grown by the respondents.

Our analysis also focused on network patterns within subsites in Kenya and Uganda. In Kenya, we found the Nyakach subsite has a higher mean centrality than other subsites in either country, suggesting more connections between farmers and higher levels of farmers giving seed and information as opposed to receiving. Though the densities of all five subsite networks are fairly low, suggesting these networks are not strongly connected, Uganda's subsite Kyabigambire is the lowest. This low density in Kyabigambire's network also influences its low betweenness, causing exchanges to occur more slowly and less often here than in other Kenyan subsites. On the other hand, the high level of betweenness in Kenya's subsites and the shorter distance between nodes in these networks suggest that information would flow faster, and that certain individuals in subsites like Sigowet with extremely high betweenness are crucial to the success of the networks. Overall, these statistics further suggest Kenya's networks, such as in Nyakach and Sigowet, are more connected than Uganda's networks.

These patterns that have emerged in the network statistics Kenyan and Ugandan subsites further explain the general trends in the two countries and the methods which should be used to enhance access to seed and genetic diversity depending on country and region. Overall, we found that targeting specific individuals in the highly dense Kenyan subsite networks will be the most successful, while using a multi-pronged approach to target the fragmented networks in Uganda will be most suitable. Comparing the Kenyan subsite Sigowet, a typical subsite in Kenya in terms of information flow, with the Ugandan subsite Kyabigambire provides an example of these two approaches. As you can see in figure 16a, the high betweenness in Sigowet's farmers suggests a faster flow of information and seed among these networks. The figure also highlights the high betweenness of a many individual farmers in these networks; specifically, the nodes highlighted in red represent farmers with a betweenness of 230 or greater, suggesting that seed exchanged through these farmers could reach up to 230 other individuals in the network. This clearly exemplifies an opportunity to target individuals within Kenyan subsite networks in order to increase access to genetic diversity and improved seed varieties. Alternatively, figure 16b shows how Ugandan subsite Kyabigambire is more disjointed and has a substantially lower level of betweenness, suggesting an alternative and more broad method of enhancing access to seed and information.

5.5 Climate Change

Climate change is an overwhelmingly prominent issue for smallholder farmers in Kenya and Uganda, with more than 90% of respondents from both countries claiming they have experienced climate related challenges. This helps to explain the prevalence of sorghum as a widely used crop among Kenyan farmers

(Martin et al. 2013, Reynolds 2015) to combat drought, increased temperatures and shifting seasons, among other specific climate related challenges. Yet, a very small portion of respondents utilize distinct seed varieties meant for adapting to climate change, such as drought tolerant varieties, despite the fact that utilizing genetic resources to resist climate change stressors has been recommended as a successful strategy to combatting climate-induced challenges (IPCC 2014).

6. Policy Recommendations

Based on the household survey data and the corresponding analyses, there are several ways that climate change information and diverse seed exchange between rural farmers in East Africa can be improved and expanded. Local systems clearly have a large influence on seed distribution, which was seen with farmers' own seed being the most important source of seed in both Kenya and Uganda. In order to improve seed distribution, government and organizational influences might direct their efforts towards more localized and informal forms of seed exchange. This could include targeting local markets or increasing the use of seed fairs, which was found to enhance local seed networks in Marambo Village, Tanzania (Nathaniels & Mwijage 2000). Field days and agri-shows were the most common source of seed information among the respondents in this survey, showing great potential for increasing access to information about genetic diversity and climate change.

Additionally, organizations could be used as a source of seed and information distribution since approximately half of surveyed Kenyan and Ugandan farmers are involved in a local farm-related organization. For example, organizations could be given information about improving the genetic diversity of crops to distribute to their members. Specific experts from certain organizations may also serve as beneficial people to distribute information and seeds to rural farmers.

Our network analysis showed a stark difference in the strengths of seed networks between genders and countries, so different policy interventions may be necessary among these different groups. Since Kenya has much stronger person-to-person and crop networks, targeting individuals or organizations may help improve information exchange in these areas. The high centrality and betweenness in female networks in Kenya indicates that targeting a woman in this network with high betweenness could lead to the distribution of seed and information throughout a large portion of the network. In Uganda, however, targeting other methods of seed distribution such as the field days and agri-shows may be most effective.

Lastly, our literature review found that agricultural extension services were meant to be a crucial source of information exchange and seed resources for rural farmers (Muyanga et al. 2006). However, our analyses indicate that extension services had little to no presence in these regions since only six respondents in both countries listed them as a source of seed. Governments and local institutions could improve the efficiency and accessibility of extension services in order to enhance information and seed exchange. Alternatively, governments could shift resources and funds from relatively ineffective services to more localized efforts, such as those indicated above.

Strengthening these informal seed networks and building the connections between the formal and informal sector is crucial in order to provide farmers with improved seeds and other farming practices. Overall, improving the dissemination of climate change adaptation information will enable farmers to increase the genetic diversity of their crops and be more resilient in the face of climactic changes.

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