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Smallholder social networks: Advice seeking and adaptation in rural Kenya

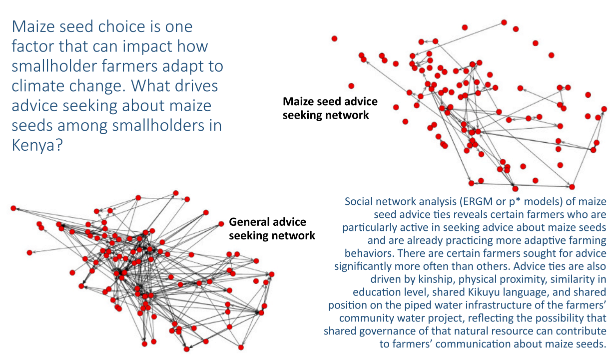
Stacey Giroux [a,b,*], Patrick Kaminski [c,d], Kurt Waldman [a,e], Jordan Blekking [e], Tom Evans [f], Kelly K. Caylor [g]

[a] Ostrom Workshop, 513 N. Park Avenue, Indiana University, Bloomington, IN 47408, USA
[b] Department of Anthropology, 701 E. Kirkwood Avenue, Indiana University, Bloomington, IN 47405, USA
[c] Department of Sociology, 1020 E Kirkwood Ave, Indiana University, Bloomington, IN 47405, USA
[d] Luddy School of Informatics, Computing, and Engineering, 700 N. Woodlawn Avenue, Indiana University, Bloomington, IN 47408, USA
[e] Department of Geography, 701 E. Kirkwood Avenue, Indiana University, Bloomington, IN 47405, USA
[f] School of Geography, Development & Environment, 1064 E. Lowell Street, University of Arizona, Tucson, AZ 85721, USA
[g] Department of Geography, 1832 Ellison Hall, University of Santa Barbara, Santa Barbara, CA 93106, USA

HIGHLIGHTS

- Using improved seed varieties is one way smallholder farmers in Africa can adapt to climate change.
- We investigate smallholders' advice seeking about maize seeds.
- There are some farmers who are significantly more active in seeking advice about maize seeds.
- Farmers seek each other out on the basis of homophily, among other social and ecological factors.
- However, maize seed technology is not a topic about which many farmers in this network seek advice.

GRAPHICAL ABSTRACT



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ABSTRACT

CONTEXT: Smallholder farmers in Africa are among those most impacted by climate change. Employing strategies such as planting early maturing or drought tolerant hybrid seeds is one common climate adaptive strategy for these households. However, seed choice has become increasingly complex for farmers. One way farmers look for clarity about seeds is to consult with other farmers.
OBJECTIVE: We investigate smallholders' advice seeking within the context of a community water project in rural Kenya, a type of community-based common pool resource management organization. We examine a maize seed advice seeking network and compare it with a more general advice seeking network to better understand the social networks of maize seed advice seeking, and to characterize how peer-to-peer advice networks might factor into farmer decision-making about seeds.
METHODS: We use exponential random graph modeling for the maize seed advice and general advice networks to test what factors predict advice-seeking among farmers in 104, or 92% of households in the community water project.

* Corresponding author at: Ostrom Workshop, 513 N. Park Avenue, Indiana University, Bloomington, IN 47408, USA.
E-mail address: sagiroux@indiana.edu (S. Giroux).

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RESULTS AND CONCLUSIONS: The maize seed advice network is less dense than the general advice network, with farmers on average seeking out fewer people for advice about maize. The features that shape each network also differ. There are some farmers who are significantly more active in seeking advice about maize seeds, and farmers who are already employing more adaptive practices on their farm are more likely to seek such advice. Farmers also seek each other out based on homophily, kinship, and physical proximity, and some farmers are sought out more often. We find evidence that physical infrastructure of the community water project drives advice-seeking ties, where farmers who are attached to the same branch of the water infrastructure are likely to seek advice from each other.

SIGNIFICANCE: Maize seed is not a topic about which many farmers in this network seek advice, and those who might be perceived as more experienced or educated are not necessarily those most sought for advice. Farmers hold key information due to their on-farm experience, and in the absence of robust extension services and consistent information about hybrid seeds, it is unclear to what extent the advice seeking that farmers do undertake fills those gaps. In addition, co-management of a common-pool resource facilitates advice sharing in both the maize and general advice networks, that is, on topics outside of the immediate reason for being part of a CWP, which is water management.

1. Introduction

Climate change disproportionately affects the farming systems of smallholder farmers reliant on rainfed crop cultivation (Jarvis et al., 2011). Improving farmers' adaptive capacity therefore is crucial to ensuring food security for these populations. One strategy, of many, that smallholder farmers employ to mitigate the effects of climate change on yields is to select seeds developed for variable growing conditions (Burnham and Ma, 2016; Chikobvu et al., 2014; Harmer and Rahman, 2014). For many farmers in east Africa, maize is the predominant crop grown and accounts for over half of calories consumed (McCann, 2005; Smale et al., 2013). While farmers have been using local landraces for generations, 80% of the households in Kenya now plant both local and hybrid maize varieties (Almekinders et al., 2021). Farmers can choose from a variety of maize seeds, but deciding which seeds will yield the largest harvests given uncertain climate conditions is a difficult choice, and one that must be made regularly. In choosing, farmers select among seed varieties bred for different maturation periods, pest resistance, herbicide resistance, disease resistance, altitude tolerance, drought conditions, taste, and yield, among other desirable traits (Lunduka et al., 2012). Farmers can choose from among locally-developed maize varieties, which are open-pollinated, or improved seeds. Improved seeds include open-pollinated or hybrid varieties that are developed by government or commercial entities specifically for desired traits. While hybrid varieties tend to have higher yields than open pollinated varieties, seeds saved and used after the first year of planting (commonly referred to as recycled) often undergo genetic changes that lead to the loss of hybrid vigor for the second generation. As a result, the second generation tends to underperform in terms of those desired traits for which they were initially purchased, as well as provide lower yields (Morris et al., 1999). Today, the choice of an optimal seed can be cognitively challenging given the range of choices available to farmers and the difficulty in matching emerging technologies with changing climate conditions (Waldman et al., 2017). With an increasing number of seed varieties from which to choose, farmers may struggle to obtain information and advice to make decisions that enhance the resilience of their farming systems. The complexity of seed decisions is compounded by issues such as insufficient extension services (Davis, 2008), seed quality concerns (Barriga and Fiala, 2018), and counterfeit inputs (Ashour et al., 2016).

Research into farmer seed choice has typically focused on individual preferences for seed attributes and examined a particular set of forces driving seed choice, including agronomic characteristics of seeds, household-level farm characteristics, perceptions of whether and how the local climate is changing, and socioeconomic variables (Asrat et al., 2010; Fisher et al., 2015; Smale et al., 2001; Stevens and Winter-Nelson, 2008; Waldman et al., 2014). Previous network studies focus on the spread of hybrid seed or other technology (Cadger et al., 2016; Matuschke and Qaim, 2009) and more recently on the physical spread of landraces (Calvet-Mir and Salpeteur, 2016; Labeyrie et al., 2016) and information or knowledge sharing (Nyantakyi-Frimpong et al., 2019; Wang et al., 2016). In the current study we use formal social network analysis to understand a highly specific maize seed advice network, and do so within the context of an existing social structure for natural resource management. Network studies of livelihood-related advice seeking tend to ask more generally about advice (e.g., Isaac et al. (2007) "advice on farm practices" or the "cooperative communication" in Barnes et al., 2019a). We choose to focus on a more specific livelihood-related advice topic, and ask whether we see factors that drive general advice seeking in this network also driving maize seed advice seeking in order to provide additional context about the maize seed advice network. Using formal network analysis to understand what shapes a specific advice network in such a context moves us closer to understanding differences in how farmers approach particular climate-adaptive farm management practices. While not all practices that researchers may understand to be climate adaptive are perceived primarily as such by farmers, our previous work in the study area has found that some farm management strategies *are* explicitly motivated by environmental concerns, specifically, maize seed choice (Waldman et al., 2019). With network analysis, we are able to test not only for individual attributes that drive advice-seeking, but also the social structural features of the network. In addition, because the specific advice network focuses on hybrid seed choice, we also can begin to uncover additional pathways through which hybrid seed use is or is not successful for these farmers. There is a lack of consensus about the degree to which hybrid seeds improve yields and benefits for farmers (Coomes et al., 2015). After decades of manufacturers, governments, and NGOs marketing and promoting improved seeds as a key solution to food insecurity, use of hybrids has not consistently benefitted smallholders, and those who use them still struggle to realize their potential (Blekking et al., 2020; Cairns et al., 2021). Having a sense of how and why farmers communicate with each other about hybrid seeds can contribute to understanding the reasons why this technology has not led to larger yield and food security gains for smallholder farmers in Africa.

Given that the choice of what maize seed variety to plant can be cognitively challenging, and that farmers may leverage their social networks for information and advice about adaptive practices, we seek to understand whether and from whom farmers are seeking advice that can help them make decisions about seeds. Farmers are selective about with whom they share seed, and they may be selective about with whom they talk and from whom they seek advice about seeds (Coomes et al., 2015). Nonetheless, farmers hold important information gleaned through their on-farm, real-world use of and experience with improved seeds, whereas advice or information received from extension tends to reflect crop outcomes under more controlled conditions. What farmers learn in terms of how improved seeds work on their farms and under different weather conditions is valuable for adaptation and not something that extension or seed purveyors can provide. We use a statistical network model known as an exponential random graph model (ERGM; or p^* model) to examine associations between farmer attributes and advice seeking among 104 Kenyan smallholder farming households within a common pool resource organization, a community water project (CWP), in central Kenya. We seek to understand social and institutional features that might facilitate farmers' ability to adapt to climate change, or to increase their adaptive capacity, by examining the structure and nature of the maize advice network we observe. Specifically, we ask, what individual and network structural factors drive advice seeking by farmers in this CWP? How might relationships formed in the context of collective resource management shape advice seeking?

In the remainder of the paper, we first provide a review of pertinent literature around seed choice, farmer networks, and advice networks in cooperative institutions like the CWP studied here. We describe the study site, including more information about CWPs in this area of Kenya. We then describe the statistical methods used and lay out some hypotheses about what we expect to drive the formation of advice ties. Finally, we present results of the ERGMs and discuss findings in terms of farmer adaptation and in the context of the CWP.

2. Background

2.1. Seed choice and climate adaptation

Traditionally, farmers selected seeds for local growing conditions (Lynam et al., 2010; McCann, 2005), then shared knowledge of each varieties' strengths and weaknesses with other farmers. Since the seed market was liberalized in the 1990s, private firms dominate the development of the vast majority of new maize varieties available to Kenyan farmers and across many African countries (Blekking et al., 2020). Farmers learn about these varieties through a number of actors, such as government and private extension services, agribusiness dealers, the media, and other farmers (Chikobvu et al., 2014). With privatization, a range of regional and international seed companies now disseminate information about the seeds through seed packaging and networks of extension agents and agribusinesses in addition to farmer-to-farmer interactions. The association between farmer-to-farmer social ties and information exchange about improved varieties is an important one, and may substantially improve household food security for smallholders engaged with this type of behavior (McGuire, 2008).

The environment within which farmers make decisions about seeds has changed over the last few decades, as rainfall patterns and thus planting dates have shifted (Schmidhuber and Tubiello, 2007; Wineman and Crawford, 2017). In eastern Africa, temperatures have been increasing since the late 1960s, with an abrupt change in temperature and significant changes annually since the early 1990s (Ongoma and Chen, 2017). Around Mount Kenya in particular, where this study takes place, since 1979 precipitation has been steadily decreasing during the long rains season but increasing during the short rains season, with those increases being expressed as more heavy rainfall events, which contribute to runoff and erosion in this area (Schmocker et al., 2016). In addition, in Kenya, maize yields decreased steadily for the period 1979–2012, with about two-thirds of that yield variance being accounted for by varying seasonal climate indices (Mumo et al., 2018). Projections of maize yield changes in Kenya by the 2090s range from −6% to −11% across different climate scenarios (Adhikari et al., 2015).

While the focus of the present study is farm-level adaptation, the decisions about seed choice specifically (and adaptive measures more generally) that these farmers make are embedded within a broader resilience context with multiple temporal and spatial features (Adger et al., 2011; Eakin and Wehbe, 2009). We consider maize seed choice in the context of changing growing conditions to be an adaptation as it is a choice made in response to expected weather impacts and is intended to mediate such impacts. The resilience implications of such reliance on hybrid seeds are unclear, and resilience impacts can be positive or negative (Nelson, 2011). For example, in the short term, at the farm level, hybrid seeds have the potential to help farmers be more successful in terms of yield and ultimately food security (though this has been debated), thereby improving their household-level resilience to climate impacts. But at larger scales, and over time, reliance on hybrid seeds could have negative impacts on system resilience to climate change, including the loss of local knowledge, loss of self-sufficiency due to reliance on hybrid seeds, poorer households being less able to adapt due to the cost of hybrid seeds and associated inputs (e.g., fertilizers), and loss of crop genetic or other biodiversity.

2.2. Farmers and networks

At least as early as the 1940s, communication among farmers has been documented as an important factor in uptake of farm practices (e.g., Ryan and Gross, 1943, 1950; Rogers and Beal, 1957), including new technology such as hybrid seed use (Matuschke and Qaim, 2009). In general, farmers in developing areas cite other farmers as their most trusted source of information (Rogers, 2010). Human social networks have been shown to be important for a range of agricultural activities, such as cultivation of new crops (Boahene et al., 1999), agroforestry innovations (Martini et al., 2017), exchange of seeds (Abay et al., 2011; Labeyrie et al., 2016; Calvet-Mir and Salpeteur, 2016), and adoption of other agricultural technology (Cadger et al., 2016; Carter et al., 2014; Maertens and Barrett, 2013; Magnan et al., 2015).

Most farmer network studies focus on the adoption or implementation of novel technology or crops, sometimes involving experiments, development interventions, or direct farmer training. Many focus on communication, transmission processes, and learning, and relate these to farming outcomes. Features such as membership in common associations, kinship, education, geographical proximity, residence in the same village, the length of time people know each other, and holding a leadership role in the community are often positively associated with farmers forming information network links for different crops (Muange et al., 2014). Network studies have also identified barriers or patterns in communication that affect information spread and learning. For example, heterogeneous growing conditions and population characteristics of farmers can impede both information flow and learning within networks (Munshi, 2004), as can different levels of educational attainment (Muange et al., 2014). In addition, the ways that ethnic groups seek out and share information among themselves can vary, for example, with members of one ethnic group serving in effect as gatekeepers of information (Gonzalez Gamboa, 2014).

Other work has used network models that focus on the structure of smallholder networks, similar to the methods described in this study, to understand social processes at work in activities such as seed sharing (Labeyrie et al., 2016), livestock management (Ortiz-Pelaez et al., 2012), and information exchange, including advice seeking in particular (Nyantakyi-Frimpong et al., 2019; Wang et al., 2016). For example, Isaac et al. (2007) investigated general farm advice networks among cocoa farmers and uncovered a pattern to the networks that was consistent across four farming communities, with the most sought-after farmers serving as bridges to external information (e.g., from the government). A study by Nyantakyi-Frimpong et al. (2019) highlighted clustering of advice seeking around certain farmers who were more successful in terms of agroforestry techniques, thereby characterizing these networks as being structured around knowledgeable farmers. A more complex, multi-level model of farmer advice seeking (Wang et al., 2016) identified factors such as a decreased likelihood for the more often sought, or “popular”, farmers to communicate with each other, in addition to finding that individual farmer attributes like religion and location drive advice sharing.

2.3. Advice seeking within an organization

In addition to research into farmer networks generally, there is a large body of literature examining (typically Western) organizations that has produced a number of findings and theories about whom individuals seek out for advice and reasons for soliciting particular people (Monge and Contractor, 2003). People do not necessarily seek the person with the most expertise for advice but are also often motivated by factors such as accessibility (O'Reilly, 1982) or comfort level, since asking for advice can mean revealing a lack of knowledge (Casciaro and Lobo, 2008). We may be more likely to turn to those who are more similar to us in terms of values, attitudes or other attributes (McPherson et al., 2001) because relationships with these people can be more satisfying as well as self-reinforcing (Lazarsfeld and Merton, 1954), and it is easier and more efficient to communicate with others who are more like ourselves (Coombs, 1966).

The process of advice seeking has been theorized in multiple ways. Cross and Borgatti (2001) describe the search for information as a function of three specific factors: how much of the knowledge of a potential advice-giver is known and valued by the advice-seeker, the accessibility of the advice-giver, and the cost of seeking advice from that person. Social exchange theory suggests that people are in effect exchanging status recognition for advice, because advice is sought based on the status of the advisor (Blau, 1955, 1964). Individuals would therefore avoid asking for advice from those with a lower status than their own. Lazega (2012), however, notes that in order to guard against potential negative effects of such status-advice exchange, individuals will seek out others who are also similar to them in some respect, thereby reducing the social transaction costs in an advice-seeking episode (see also Lazega and Van Duijn, 1997). Social capital theory offers yet more drivers of advice-seeking behavior, including for example overall network structure; relationships with others that embody trust and friendship; and homophily in values and meaning between advice seekers and givers (Nahapiet and Ghoshal, 1998).

2.4. Advice networks within cooperative institutions in social-ecological systems

While the context within which this study takes place, a cooperative institution in an African setting where people are managing common-pool resources (CPRs) in a social-ecological system (SES), could be thought of as an organization, it is different from those studied in much of the literature about advice-seeking networks in organizations. CWPs are local institutions (Andersson and Ostrom, 2008; Ostrom, 1990) which are part of a larger, polycentric system of water governance in Kenya (Baldwin et al., 2016) and are embedded within a social-ecological system. The CWP, as an institution, creates a foundation of social capital and can foster beneficial social features such as trust among members (Ostrom and Ahn, 2003). Institutions, particularly rural ones, also shape adaptation and adaptive behavior (Agrawal, 2009). While CWP members may certainly share knowledge and information about water use, the CWP is more strongly defined by joint, collective management of a CPR.

Much recent research on the structure and formation of information and advice networks in cooperative institutions that manage CPRs comes from work studying fishers and fisheries. Drivers of ties that cover a range of network structural, attribute, and exogenous factors have been tested in such settings. Structural drivers are those influenced by already existing direct or indirect connections (Lusher et al., 2013; Rivera et al., 2010). For example, with the structural feature known as preferential attachment, actors will tend to form ties with people who are already connected to others, and this would be evidenced by higher network centralization measures. Attribute-based drivers include, for example, homophily, or factors that actors in a network share (or do not share), and cover a broad range of variables, from kinship to gender to skill and experience. Exogenous factors are environmental features that may drive ties, including geographic factors or being part of other kinds of networks. Alexander et al. (2018), studying Jamaican fishers' exchange of fishing-related information, found triadic closure, or a kind of bonding tie where one's contacts or friends are likely to also be connected with each other, to be a significant driver, as well as homophily in fishing gear used. Barnes et al. (2019a, 2019b) focused on ties of "cooperative communication," which extended beyond specifically advice seeking or sharing and included information and knowledge exchange about fishing and fishery management. Drivers of ties included a tendency for fishers to form ties with community leaders, with other fishers using the same landing site, with fishers of the same gender, and for fishers to cluster into triads.

3. Study site

The study site is located within the Likii subcatchment, which is part of the Greater Nanyuki river system, on the northwestern slopes of Mount Kenya (Fig. 1). Smallholders in this area plant and harvest according to two rainy seasons, which begin in March/April (long rains) and October/November (short rains). However, rainfall and temperature in the region have become increasingly variable in the last few decades (Ongoma and Chen, 2017; Schmocker et al., 2016). Currently, the subcatchment is mainly inhabited by smallholder farmers, most of whom are members of the Kikuyu and Meru ethnic groups. The area has experienced marked population increase since the mid-twentieth century, mostly due to farmers seeking land (Ngigi et al., 2007).

With increased population has come increased demand for, and potential conflict over, water resources. As a result, the formation of formal water resource users' associations (WRUAs) began in earnest in the late 1990s. These associations are intended to coordinate water use and management by water users and stakeholders, and to resolve disputes among parties (Baldwin et al., 2016). WRUAs are composed of different types of water users in a catchment including commercial farmers, municipal water systems, and communities of small-scale farmers, known as community water projects (CWPs). Initially developed to provide only domestic water, CWP members may now utilize water for irrigation, though in practice, the water provided is not enough for consistent irrigation and farmers remain reliant on rainfall.

Resource management systems such as these CWPs rely on a strong institutional structure, that is, the rules put in place and enforced by the individuals using the water resource, for success. Superior technology or infrastructure alone will not guarantee equitable water delivery – a well-designed and functioning institution is crucial (Ostrom and Gardner, 1993). CWPs are community-level organizations whose members collectively develop rules for water allocation and sanctions for misuse. For example, the management committee of a CWP is elected by its members and is responsible for developing guidelines that help ensure all members receive water, such as rationing schedules that go into effect when river levels are low. CWP members pay a flat fee to join and maintain membership in the project. In some CWPs, members may be required to participate in project governance (e.g., attend meetings) and maintenance of the piped infrastructure. Additional features of CWPs in this area, such as time established, size, membership, and rules range widely (see McCord et al., 2017 for more information about CWPs in this area). CWPs manage water resources distributed through pipe infrastructure that directs water from the river to member households. The piped infrastructure of this CWP is set up with a single intake point, with households positioned along pipes extending outward from this point. Households are then attached to motors, which are located within clusters. Each cluster has up to five motors, and up to five households can be attached to each motor.

In addition to CWPs, individuals in this study area may also be members of other local social organizations such as agricultural cooperatives, women's groups, or other social organizations, which can function as additional sources of advice about maize seeds or other farm management topics and techniques. $<$15% of the farmers in our sample were members of a specific agricultural group, but over half the respondents in our sample were members of some other kind of social group, such as a self-help group or financial support group.

Finally, as described earlier, reliance on hybrid maize seeds is high in

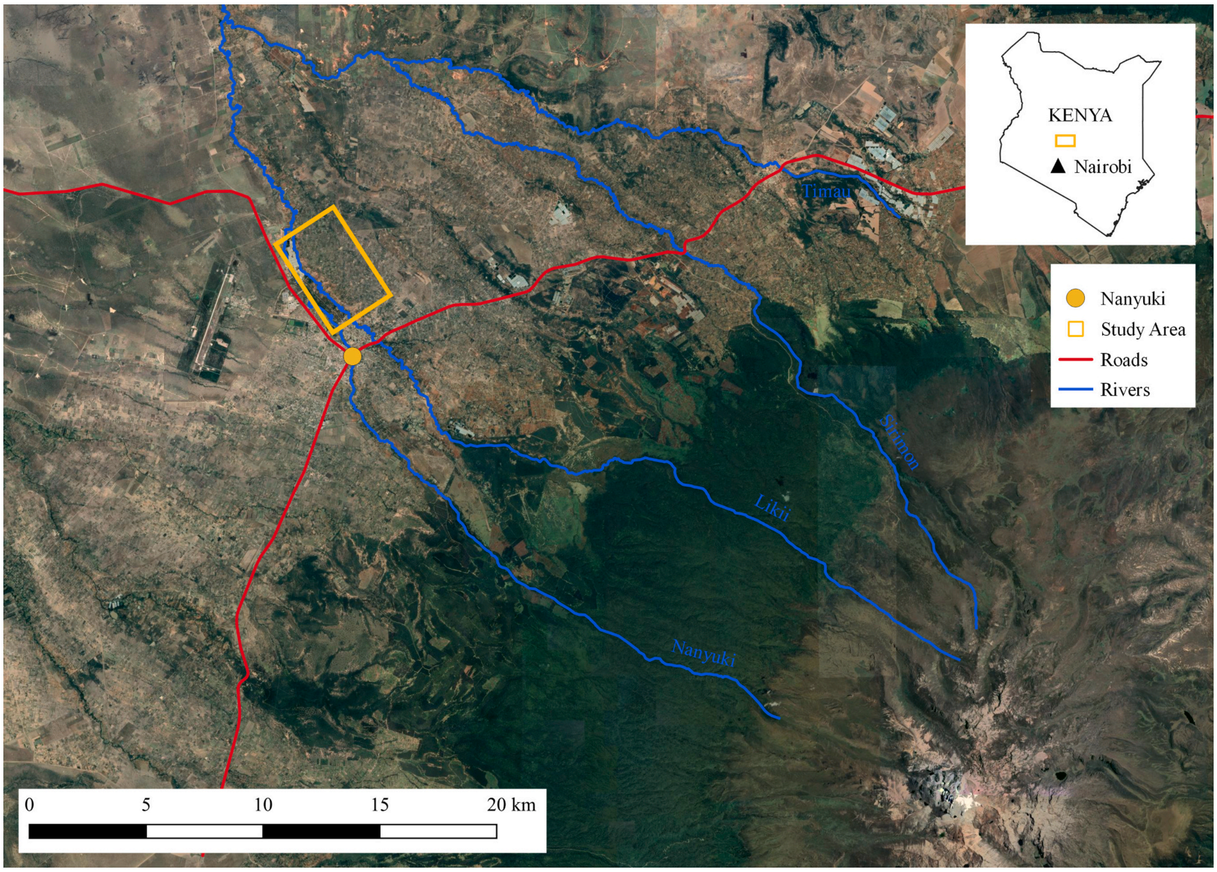

Fig. 1. Map of Likii subcatchment, which contains the study site.

this area. To provide a sense of that reliance as it pertains to this sample, we asked farmers to tell us what varieties of maize seeds they intended to plant in the upcoming season. Only five of the 104 farmers (4.8%) said they were planning to use recycled seed alone.

4. Methods and analysis

We took a whole network approach, focusing our analysis on the pattern of relationships within a defined group of households rather than focusing on the relationships of each individual household. To that end, we attempted to interview all 113 CWP member households, and succeeded in interviewing 104, or 92% of all households in the CWP in February of 2017. We did not interview the CWP chairman's household because he was engaged in additional activities of the broader research project within which this study was embedded; one household requested that we not attempt to interview due to one of its members being seriously ill; and the seven remaining households we abandoned after three failed attempts to reach them.

At each household enumerators interviewed the person most knowledgeable about the farming decisions made on the farm. This was typically, but not always, a male head of the household. Enumerators used tablets with the survey programmed in Qualtrics to capture responses. Farmers were asked a set of demographic questions, questions about their maize growing over the last season (e.g., did they plant in both the short and long rainy seasons, seed varieties planted), and a set of network questions designed to elicit information about advice seeking in general and about maize seed advice seeking from other households in the CWP in particular. We gave each respondent a list of the households in the CWP, indicated by both the name under which the CWP membership was filed and, where applicable, a more local name or nickname for that household or its head. In terms of name generators, we asked, "Which households in the CWP have you talked to about challenges your household experiences and general advice in the last two weeks?" And, "Which households in the CWP have you consulted at all for advice or information related to what maize varieties you're planting this season [which was starting] in March/April 2017?" We refer to these two networks as the general advice network and maize advice network, respectively, in the rest of the paper. We asked an additional question that would allow us to create the covariate for kinship: Are you or your spouse related to anyone in any of these households [in the CWP]? We then took latitude/longitude coordinates at each house to create the covariate for household proximity in terms of Euclidean distance. Finally, with the help of the CWP secretary, we were able to obtain a list that described how each household was connected to the piped infrastructure in terms of cluster and motor.

We use ERGMs to understand what factors help predict the formation of an advice-seeking relationship between farmers. In this way, ERGMs can be thought of as analogous to logistic regression, but the crucial difference is that these models account for dependence of observations. ERGMs allow for modeling of endogenous and exogenous processes that generate the observed network structure (Morris et al., 2008). Endogenous factors are smaller structures, or configurations, in a network that represent social processes such as reciprocity (an actor chooses another actor, who chooses them in return) or triadic closure (a friend of a friend is my friend) and give rise to the observed larger network structure (Lusher et al., 2013, p. 18). Exogenous factors involve node-level, in this case, farmer household-level attributes like highest level of education achieved or physical distance from other households. These exogenous factors can influence social processes and can impact the overall network structure. We used the statnet suite of R packages for analysis (Statnet Development Team, 2003–2022).

The general form of an ERGM estimates probability of the entire network as a function of terms that represent network features that may occur more or less likely than expected by chance. This equation is as follows:

$$P(Y = y) = \frac{exp(\theta' g(y))}{k(\theta)}$$

Where

Y is the random variable for the state of the network (with realization y),

$g(y)$ is a vector of model statistics for network y,

θ is the vector of coefficients for those statistics, and

$k(\theta)$ represents the quantity in the numerator summed over all possible networks.

In this analysis, we want to understand the conditional log-odds of a single tie between two nodes, so:

$$logit\left(Y_{ij} = 1 \middle| y_{ij}^c\right) = \theta' \delta(y_{ij})$$

Where

Y_{ij} is the random variable for the state of the node pair i, j (with realization Y_{ij}), and

y_{ij}^c signifies the complement of Y_{ij}, that is, all dyads in the network other than Y_{ij}.

$\delta(y_{ij})$ is a vector of the "change statistics" for each model term. The change statistic records how the $g(y)$ term changes if the y_{ij} tie is present or not (Statnet Development Team, 2019).

The variables tested and their associated hypotheses are summarized in Table 1. The exogenous variables we include in our models relate to different factors that might influence advice seeking. For many of these variables, we test for both the main effect and for homophilous relationships, or those ways in which farmers may be similar (or dissimilar) to each other that would drive advice seeking. We do this because the nature of these effects may drive advice seeking, but also because homophily could be the underlying mechanism for tie formation independent of the main effect (e.g., Kikuyu speakers might not seek more advice ties, and thus the main effect of language is insignificant, but language could have a significant homophilous effect). The number of years a household has been a member of the CWP and the number of years a household has been established both function as measures of established relationships and trust. It may be that farmers seek each other out for advice because they have worked together in the CWP for a long time or have been friends for a long time. A household established longer may also have more experience farming in this particular area, and we use two additional measures of farmer experience and knowledge: education level of the household head, and how many of nine adaptive farming behaviors (plant an early maturing maize variety, plant a late maturing maize variety, mix different varieties of maize to spread risk of crop failure, plant a drought resistant crop instead of maize, leave a field fallow, diversify crops, use reservoir or pond for water harvesting, practice conservation farming, practice crop rotation) employed in the six months prior to the survey. The adaptive behaviors were first drawn from a meta-analysis of climate change adaptation decisions made by farmers (Burnham and Ma, 2016), which we then tailored to the Kenyan context through discussion with local experts and field testing. The survey asked about 20 behaviors, and in this analysis, we focus on the nine directly connected to seeds, planting, and growing. Those not used in this analysis included behaviors less directly tied to crop farming, such as selling livestock or seeking off-farm work. We were not able to include a measure of farmer productivity as a proxy for experience, as we intended, because over 80% of the farmers in our study experienced complete crop failure in the last harvest due to drought. A farmer practicing more adaptive behaviors, some of which have to do directly with maize variety choice, might be someone who is sought out more often for advice. Farmers may also seek out those with more education than themselves, since some studies have found that farmers who are literate are more likely to adopt new technology (Bandiera and Rasul, 2006). We include whether the respondent's first language learned (mother tongue) is that of the dominant ethnic group (Kikuyu) as a proxy for ethnic affiliation, and hypothesize that farmers will be more likely to seek each other out if they share an ethnic background (e.g., Barnes-Mauthe et al., 2013). Location on the physical infrastructure of CWP, measured by which cluster the household is on, allows us to test whether the set up for management of the shared

Table 1
Summary of hypothesized drivers of advice seeking in the networks.

Variable	Measure	Hypothesis
Years household established here	Trust, friendship	Those living in the area longer will seek out others living in the area longer (Muange et al., 2014)
Years household established here	Farming experience	People with more years living in the area will be sought more for advice (Rogers, 2010)
Years CWP membership	Trust, friendship	Those in the CWP longer will seek out others in the CWP longer (Ostrom and Ahn, 2003)
Education of household head	Farming experience, willingness to try new technology	People will not seek out those with the same education level as themselves (Mekonnen et al., 2018)
Number of adaptive behaviors (maize network only)	Farming experience, willingness to try new technology	People will seek out those undertaking more adaptive behaviors than themselves (Nyantaki-Frimpong et al., 2019)
Mother tongue	Key personal characteristic	People who speak the same first language will be more likely to seek each other for advice (Barnes-Mauthe et al., 2013)
Position on CWP piped infrastructure	Factor related to collective action to manage natural resource	People sharing a cluster will be more likely to seek each other out for advice (Barnes et al., 2019b; Ostrom and Ahn, 2003)
Sought maize seed advice outside CWP (maize network only)	Propensity for activity	People seeking advice outside the CWP will be more likely to seek it inside (Badstue et al., 2018); or, the more connected one is outside the CWP, the more connected one will be with CWP members
Household location	Proximity	People will be more likely to seek out those located physically closer to themselves (Doreian and Conti, 2012; Wang et al., 2016)
Kinship	Key personal characteristic	People will be more likely to seek kin for advice (Mekonnen et al., 2018)
Triads and transitivity	Network structural factor	People will have shared advice partners (Alexander et al., 2018); that is, person i and person j both seek advice from person k
Reciprocity (general advice network only)	Network structural factor	A person seeking advice from someone will in turn be sought for advice by that person (Blau, 1964)
In-degree	Network structural factor	Some people will be sought for advice more than others (Nyantaki-Frimpong et al., 2019)
Out-degree	Network structural factor	Some people will be more likely to seek advice than others (Isaac et al., 2007; Lusher et al., 2013)

resource drives to whom farmers turn for advice, and lets us more directly integrate some of the "ecological" in this social-ecological system (Barnes et al., 2019b). We could not use coding to the more detailed cluster and motor level as it resulted in too many small cell sizes making the estimation of effects infeasible. We also consider whether maize advice was sought outside the CWP to test whether some farmers might be more active advice seekers in general. This last variable, as well as the count of adaptive behaviors, were dropped in testing the general advice network because they are maize-specific.

We include a geospatial variable as a dyadic covariate: household proximity is an exogenous factor that we hypothesize to be important for tie formation in this network, as spatial context often shapes social interaction, including farmer communication networks (Doreian and Conti, 2012; Wang et al., 2016). We also treat kinship as a dyadic covariate, and expect this to be a significant driver of ties in this network as it has been in numerous other farmer seed networks.

We note, however, that kinship was not reported symmetrically in the data, as one might expect. We suspect that due to the expansive nature of the question, which asked for kin relations for either the respondent or respondent's spouse with anyone in any of the other >100 households in the CWP, respondents likely forgot some ties. In order to account for potential errors and to see how sensitive our results are to changes in the kinship ties, we conditioned each of the advice seeking networks on three different versions of the kinship data: 1. the original, asymmetric kinship data; 2. a strongly symmetrized version in which a kinship tie only exists if both respondents reported kinship; 3. a weakly symmetrized version in which the presence of any reported kinship tie is considered to be a mutual tie between households. Given our assumption about reporting errors, we consider the weakly symmetrized version to most reasonably reflect what might be the "true" kinship relations among households in the CWP, and present model results for the weakly symmetrized data below. While the model results do differ slightly across the different symmetrizations, the overall results are fairly stable across the different specifications and additional results can be found in the Appendix.

In terms of endogenous, or network structural factors driving tie formation, transitivity is a common feature of human social networks, and prior work on social-ecological networks has found triadic structures to be important (e.g., Alexander et al., 2018). Triadic structures involve three nodes, and an example of transitivity is where person *i* is connected to person *j*, and both are connected to person *k*. We expect to find triadic structures in these two networks as well. While reciprocity tends to be a feature of many social networks (Blau, 1964), we do not expect reciprocity to be a driving factor of maize advice ties. That is, we do not expect that person *i* who is asked for advice about maize seeds by *j* will in turn ask *j* for advice about maize seeds. While reciprocal advice seeking no doubt happens, we do not believe it happens enough to be a significant driver of maize seed advice seeking in this network. Some of our hypotheses relate to farmer experience, and we believe that if farmer *i* is seeking farmer *j* for advice about a farming related matter, farmer *j* will, after the advice-seeking episode, perceive that they were sought because of having more experience or knowledge and will see less reason to seek advice from farmer *i* in turn. Reciprocity is more likely to be found with the general advice network, which was not constrained in terms of the topic and respondents could think about any number of challenges for which they might have sought advice. We also expect to see structure emerge in both networks in terms of people who are more often sought for advice and for people who are more active advice-seekers (Isaac et al., 2007).

We examine both the maize advice network and the general advice network for the CWP. We first provide network descriptive statistics and visualizations for each network, and then ERGM results for both networks to understand what underlies advice seeking and whether there are similar patterns between the maize seed advice seeking and general advice seeking networks. Both ERGMs attained the necessary level of goodness of fit, and tests for multicollinearity of variables (VIF) uncovered no severe collinearity (i.e., VIF > 100), though we did find elevated VIF scores (i.e., VIF > 20) for some of the clusters (piped infrastructure) for both networks, and for some of the categories of education in the challenges network (Duxbury, 2018). Goodness of fit statistics and plots as well as VIF statistics can be found in the Appendix.

5. Results

5.1. Farmer descriptive statistics

Table 2 presents descriptive statistics for the farmers on the exogenous variables included in the ERGMs. The average household has been a member of the CWP for most of its formal existence, and has been established in the area for about 20 years. Households are also taking up a number of adaptive farming behaviors, and nearly 40% have sought maize seed advice outside the CWP.

5.2. Network descriptive statistics

The number of people involved and the number of advice seeking ties varied between the two networks. In the general advice network, more households in CWP were involved, it was denser, and each node had on average four more ties (mean degree) with greater overall range (Table 3). The number of isolates, or those who neither sought advice nor were sought out, is higher for the maize network. Centralization is the extent to which a network is dominated by one node, and density is a measure of the cohesion of a network (Borgatti et al., 2018). The general advice network is more integrated overall in terms of these measures. Fig. 2 provides visualizations of each network.

5.3. ERGM results

There are some nodal and structural features that drive both advice networks, but also certain features that matter in particular for each network (Table 4). In both networks, similarity in education level of the household head, being attached to the same cluster, household proximity, and kinship are factors that facilitate the formation of advice seeking ties, and there are some households who are sought out for advice significantly more than others.

In the general advice network, we see a number of other factors matter as well. In addition to being attached to the same portion of the water infrastructure overall, being attached to certain clusters in particular is significant for advice seeking. The number of years a household has been established there, and how long households have been members of the CWP matter. Households residing in the area for a similar number of years, and those who have been members of the CWP a similar number of years, are more likely to form ties than households that have a larger difference in years of residence or years of membership. Three additional network structural parameters drive general advice seeking. Reciprocity, where households consult each other for advice, is significant. The two other parameters are more complex to

Table 2
Descriptive statistics for exogenous (farmer attribute) variables.

Variable	Mean (std. dev)	Range
Education of household head	Completed secondary school (N/A)	None, Completed post-secondary school
Years CWP membership	12.6 (4)	0.5–15
Years household established here	20 (9.5)	1–50
Number of adaptive behaviors	4.2 (1.95)	0–9
Mother tongue - majority language (Kikuyu)	0.82 (N/A)	Kikuyu, Kimeru, Turkana, Other
Sought maize seed advice outside CWP	0.39 (N/A)	yes, no

Table 3
Descriptive statistics for the general and maize advice networks.

Network characteristic	Maize advice	General advice
Number of edges (i.e., advice-seeking ties)	69	287
Proportion of isolates	39.4%	5.8%
Number of people sought by a given farmer (range)	0–4	0–24
Mean degree	1.327	5.519
Density	0.006	0.027
Centralization	0.033	0.141

interpret. In this context, the weighted edgewise shared partner parameter represents transitive triads. That is, it estimates the likelihood of two farmers forming an advice tie based on their shared advice partners, and this along with the 2-path parameter get at the notion of clustering in the network. Such a relationship is where farmer *j* is sought by both farmer *i* and *k* for advice, farmer *k* is sought by farmer *i* for advice, but farmer *i* is not sought by either farmer *j* or *k*.

In the maize advice network, the number of adaptive behaviors matters in that the more adaptive behaviors practiced, the more likely one is to seek maize seed advice. In addition, having sought advice about maize seeds from someone outside of the CWP increases the likelihood of seeking advice within the CWP. The structural parameter modeled in this network, dyadwise shared partners, is not significant. This is a relationship where farmer *j* seeks advice from farmer *i*, who seeks advice from farmer *k*.

6. Discussion

6.1. Network similarities

Examining a maize seed advice network that is specific to climate change adaptation alongside a broader advice network highlights the differences in both endogenous and exogenous network factors driving advice seeking. Farmers in the CWP clearly talk with each other and look to each other for advice, but there are differences in how they seek different types of advice. There is some overlap in what shapes the two networks, however. Kinship, a significant driver in both networks, plays an important role in social life in many ways (McPherson et al., 2001) and features in many agricultural networks, whether with respect to exchange of seeds or other plant material (Delêtre et al., 2011; Labeyrie et al., 2016; Pautasso et al., 2013), information sharing (Mekonnen et al., 2018), technology adoption (Warriner and Moul, 1992), or other activities (Di Falco and Bulte, 2013). Proximity is also a key factor in many types of tie formation, including for advice and communication networks (Small and Adler, 2019), and we find this to be key to both networks studied here. Kinship and accessibility are also implicated in theories of advice seeking more broadly. While similarity in educational level driving the general and maize advice networks runs counter to our hypothesis that farmers would seek others with more education, it is in line with other findings that have found farmers exchanging information with those who are of similar education (Muange et al., 2014). That there are particular farmers sought for advice, whether general advice or about maize seeds in particular, is also consistent with prior research. Community leaders, elders, or skilled people often emerge as important people to be consulted for advice and information (Alexander et al., 2018; Barnes et al., 2019b; Nyantaki-Frimpong et al., 2019). In terms of maize seeds specifically, those farmers who are sought out more often may be particularly knowledgeable or innovative (Isaac et al., 2007), or may have other clear, outward signs of being a successful farmer (Nyantakyi-Frimpong et al., 2019).

One farmer who was both particularly innovative and working to teach others had the highest in-degree in the maize advice network, that is, he was the one sought by most farmers for advice about maize seeds. He also had the highest betweenness centrality score (i.e., he was along the shortest path between two other farmers the most often). The two farmers most often sought for maize seed advice did not, however, report practicing a particularly high number of adaptive behaviors on farm (3 each). Nor were the farmers most sought in the maize advice network the same as those sought in the general advice network. This is likely due to the broader nature of the general advice network compared with the specificity of maize advice. We do not know all the topics about which farmers were consulting each other for advice in the general network. However, that one of the two people most often sought for general advice was an older man who had lived in the community for a quarter century suggests a general appreciation for advice from a respected person likely considered wiser or more well-versed in the world.

One of the more intriguing findings is that sharing a position on the piped water infrastructure is significantly related to forming advice ties, whether general or maize seed-specific. Institutions, such as CWPs described here, facilitate adaptation (Agrawal, 2009). From a social network perspective, this relates to recent work that has shown how, in a fishing management context, co-management of a natural resource can break down some barriers to information access, while other social, cultural, and economic barriers, including formal membership in resource management groups, structure knowledge exchange (Barnes et al., 2019a). Shared ecological resources (e.g., similarity in species fished or fishing site used) within an SES can also facilitate social ties (Barnes et al., 2019a, 2019b). Sharing an ecological resource in turn creates cross-level (social – ecological) closure that is theorized to enhance cooperators' relationships in terms of agreeing about how to manage CPRs (Barnes et al., 2019a). In our case, farmers' shared location

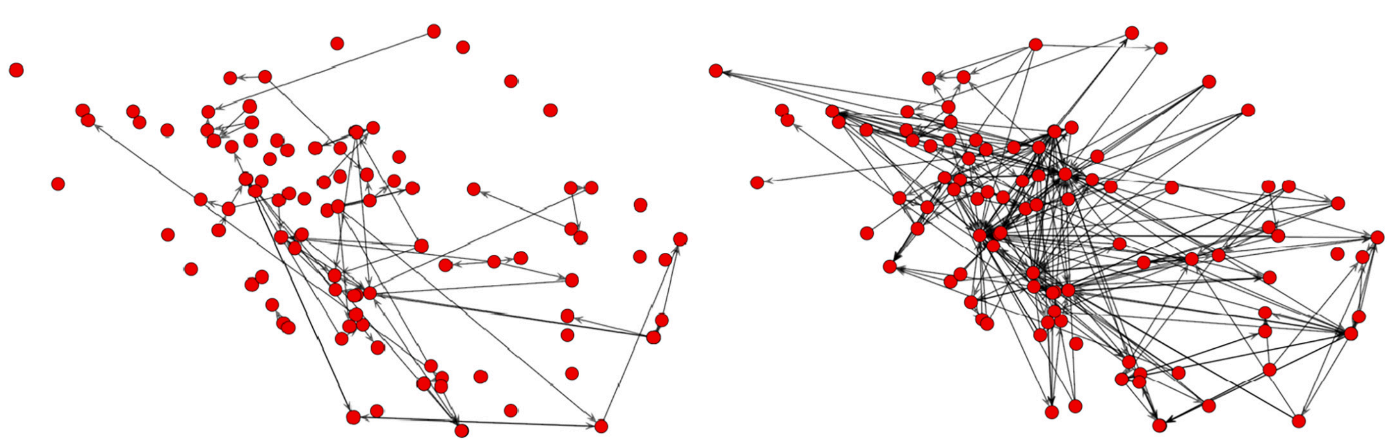

Fig. 2. Maize advice seeking network (left) and general advice seeking network (right). Nodes are positioned relative to each other using latitude and longitude. Arrows point to farmers from whom advice was sought.

Table 4
ERGM results for maize and general advice networks. In interpreting the estimates, recall that ERGMs predict the probability of a tie conditional on all other ties observed in the network. Therefore, interpretation is analogous to that for logistic regression results. Aside from reciprocity, which was not included in the maize network because we did not hypothesize it to be a factor, the endogenous variables that differ between the two networks have to do with the nature of transitivity that emerged as we modeled each network. That is, the general advice network exhibited clustering and transitivity in terms of the 2-path and edgewise shared partner parameters, but the maize advice network would not converge with these terms. These are discussed further in the next section. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

Parameter	Estimates (std. error)		Interpretation
	Maize advice network	General advice network	
Edges	−2.83 (2.85)	0.53 (1.12)	
Exogenous variables			
Kikuyu mother tongue (main effect)	0.31 (0.32)	0.08 (0.2)	
Kikuyu mother tongue (homophily)	0.89 (0.45) *	0.47 (0.25)	People who speak the same first language are more likely to seek each other out for maize seed advice
Shared position on CWP piped infrastructure (main effect; ref. Cluster 1): Cluster 2	1.37 (1.07)	0.64 (0.34)	
Shared position on CWP piped infrastructure: Cluster 3	0.85 (1.07)	0.72 (0.34)*	People attached to this cluster in particular are more likely to engage in general advice sharing
Shared position on CWP piped infrastructure: Cluster 4	1.18 (1.07)	0.69 (0.34)*	People attached to this cluster in particular are more likely to engage in general advice sharing
Shared position on CWP piped infrastructure: Cluster 5	1.58 (1.09)	0.69 (0.34)*	People attached to this cluster in particular are more likely to engage in general advice sharing
Shared position on CWP piped infrastructure: Cluster 6	1.35 (1.05)	0.62 (0.33)	
Shared position on CWP piped infrastructure: Cluster 7	1.43 (1.06)	0.65 (0.33)	
Shared position on CWP piped infrastructure (homophily)	1.26 (0.28) ***	0.76 (0.13)***	People sharing a cluster are more likely to seek each other out for both maize seed and general advice
Education of household head (main effect; ref. None): Some primary school	−0.16 (0.67)	0.1 (0.34)	
Education of household head: Completed primary school	−0.45 (0.58)	0.35 (0.32)	
Education of household head: Some secondary school	−0.68 (0.7)	0.21 (0.35)	
Education of household head: Completed secondary school	−0.04 (0.57)	0.29 (0.32)	
Education of household head: Some post-secondary school	0.37 (0.98)	0.53 (0.47)	
Education of household head: Completed post-secondary school	−0.65 (0.56)	0.09 (0.32)	
Education of household head: Unknown	0.01 (0.65)	0.31 (0.33)	
Education of household head (homophily – absolute difference)	−0.21 (0.08)**	−0.08 (0.04)*	The greater the difference in education between people, the less likely they are to form an advice tie for both maize seed and general advice
Number of years household has been established (main effect: in-degree)	−0.02 (0.02)	0.003 (0.01)	
Number of years household has been established (main effect: out-degree)	−0.001 (0.02)	0.01 (0.01)	
Number of years household has been established (homophily – absolute difference)	0.01 (0.02)	−0.02 (0.01)**	The greater the difference in the length of time people have had their household established there, the less likely they are to form an advice tie for general advice
Number of years household has been a member of the CWP (main effect: in-degree)	−0.0002 (0.05)	−0.01 (0.02)	
Number of years household has been a member of the CWP (main effect: out-degree)	−0.02 (0.05)	−0.06 (0.02)**	People who have been CWP members longer are less likely to seek general advice from others
Number of years household has been a member of the CWP (homophily – absolute difference)	−0.06 (0.05)	−0.07 (0.02)**	The greater the difference in the length of time people have been members of the CWP, the less likely they are to form an advice tie for general advice
Sought maize seed advice outside the CWP (main effect)	0.87 (0.23) ***	Not included	People who sought maize seed advice outside the CWP are likely to seek it from people inside the CWP
Number of adaptive behaviors (main effect: in-degree)	0.08 (0.06)	Not included	
Number of adaptive behaviors (main effect: out-degree)	0.16 (0.07) *	Not included	People who are undertaking more on-farm adaptive behaviors are more likely to seek maize seed advice
Kinship	2.74 (0.41) ***	1.06 (0.28)***	People who are kin are more likely to seek advice from each other for maize seed and general advice
Household proximity	−0.57 (0.11)***	−0.53 (0.06)***	People whose homes are closer together are more likely to seek each other out for maize seed and general advice
Endogenous variables			
Reciprocity	Not included	0.86 (0.35)*	People who have sought someone for general advice are likely to be sought in turn for it
2-path	Not included	−0.1 (0.02)***	Taken together, these indicate a tendency in
Geometrically weighted edgewise shared partner	Not included	0.71 (0.13)***	the general advice network toward triangles (clusters of three directly connected nodes) and less tendency for indirect

(*continued on next page*)

Table 4 (*continued*)

Parameter	Estimates (std. error)		Interpretation
	Maize advice network	General advice network	
			connections (*i* seeks *j*, who seeks *k*)
Geometrically weighted directed dyadwise shared partner	−0.18 (0.11)	Not included	
Geometrically weighted in-degree	−2.19 (0.86)*	−2.38 (0.23)***	Both networks are more centralized, meaning that some people form a core in the network and are more likely to be asked for advice on maize and general issues than other people.
Geometrically weighted out-degree	−0.67 (0.38)	−0.31 (0.35)	

on the piped water infrastructure, which can entail, for example, cooperation in terms of co-work to maintain that physical infrastructure, could be spilling over or leading to advice seeking about maize seeds among those farmers (Galizzi and Whitmarsh, 2019; Rojas and Cinner, 2020). Our study suggests that relationships formed in a social-ecological, resource management context can also be important for advice and ultimately adaptation to climate change at the farm level.

6.2. Network differences

The drivers of advice ties that differ between the two networks also include both farmer attribute and network structural variables. Reciprocity, as expected, features in the general advice network but not the maize network. Households with similar tenure in terms of time living there likely reflects friendship or other trusting relationship ties that relate to general advice seeking across any number of topics. These features of trust and friendship have been found to be important more broadly in advice seeking behavior. Transitivity, which can indicate bonding social capital and likely contributes to successful CPR management, is a significant factor in the general network but not the maize network. Prior work on advice seeking in social-ecological systems has shown transitivity to be a driver of advice seeking (e.g., Alexander et al., 2018), and when this has been found tends to be with a broader definition of advice or communication that more in line with our general advice network than the much more specific maize seed advice network we elicited. Our maize network is very sparse with low density and low mean degree, which is similar to some farmer advice networks (e.g., Faysse et al., 2012), while our general advice network, with significant reciprocity, 2-paths, and transitivity, appears to be reflecting at least to some extent the existing friendship network in the CWP, as these parameters feature in other friendship networks (Lusher et al., 2013).

Shared mother tongue, or ethnic background, is significant in the maize seed advice network but not in the general advice network. Shared ethnicity is a key homophilic feature, if inconsistently found to be significant, in the literature on networks in CPR and agricultural settings (e.g., Barnes et al., 2019a; Barnes-Mauthe et al., 2013). In this case, shared Kikuyu language was not a significant driver of ties in the general advice network. Perhaps this is a feature that matters for people but is not as important in every advice context, whereas something like kinship, which has been much more consistently shown to be important in agriculture and seed-related networks, was significant in both the networks examined here.

Parameters specific to the maize advice network, the number of adaptive behaviors undertaken in the last six months and whether a person sought advice about maize seeds outside the CWP, also drove advice ties. These paint a picture of certain farmers who are undertaking multiple climate-adaptive farm management practices and are actively seeking advice about one of them, namely maize seeds. Farmer seed advice networks are especially important to using hybrid seeds successfully given issues like information disconnects between farmers and seed companies or vendors (Waldman et al., 2017), or the simple fact that on-farm experience of others cannot substitute for extension advice. There appears to be a set of farmers who behave differently from the rest in the CWP in terms of advice seeking and are actively working to learn from others about maize seeds, even if they are already employing a number of adaptive practices. It is equally important to note that those farmers who do practice more adaptive behaviors are not particularly sought out for advice, which we hypothesized would be a driver of advice seeking for households. Not all farmers are seeking advice about maize seeds, and this could be for any number of reasons, including economic inability to take any advice, aversion to risk or trying something new, or lack of self-sufficiency in the sense that they feel they cannot do much to change their farming outcomes.

6.3. Farmer advice networks

Network analysis of farmers' information and advice sharing has revealed how complex, specific, and nonlinear farmers' networks are. The maize seed advice network described here also shares these characteristics. Networks are complex in terms of who is sought for what kind of information, at what point in the decision making process particular people are sought, and how these all relate to farmer uptake of farming practices and new technology. Such research has revealed how information and knowledge transfer is often not linear (e.g., scientists to farmers via extension agents) nor is it consistently patterned in terms of knowledge radiating out from a central farmer. Rather, knowledge is shaped and co-created by farmers in their information networks. The technology under consideration also shapes advice networks and what have been referred to as microlevel agricultural knowledge and innovation systems (microAKIS; Madureira et al., 2022), which include "the knowledge systems that farmers personally assemble, including the range of individuals and organisations from whom they seek services and exchange knowledge" (Sutherland and Labarthe, 2022). Farmers value empiricism and knowledge of the particular (Wood et al., 2014), whereas information generated by extension agents or seed companies, working under controlled conditions and focused on broad-scale advice, is information that is more general and needs to be supplemented with real-time, on-farm experience.

Farmers often find multiple benefits in a single information-seeking episode, including not only solutions to a problem but also help reframing a problem or becoming aware of additional sources of information, among other things (Sligo et al., 2005). Farmers may seek out different people for information at different points in the decision-making process. For example, Solano et al. (2003) found family members and technical advisors to be important at all times to Costa Rican dairy farmers, but their relative importance changed throughout the decision-making process. However, even when farmers are in similar contexts, such as in terms of growing conditions or farm characteristics, there are still differences in advice and information seeking behavior. Aguilar-Gallegos et al. (2015) identified three clusters of palm oil farmers whose information seeking behavior was linked with their level of technology adoption. Those with lowest level of adoption exhibited the most information-seeking behavior, yet they were linked the least with extension agents. This was in contrast to those who were high-level adopters, who also had high out-degree in terms of information seeking but were connected most with extensionists and were themselves most often referred to by other farmers as information sources. The middle-level adoption group exhibited the least amount of information seeking behavior and were sought the least by other farmers, yet had better yields and income than the low- level adopters.

While our study has identified some factors that are frequently found to be important in advice networks of farmers (e.g., kinship, proximity), we have also highlighted how the maize seed advice network is specific, with climate-adaptive farming information and practice significantly impacting advice seeking, and complex, showing how perceived knowledge or skill is not necessarily the driving factor in advice seeking. The network also illustrates the many ways that context can impact advice seeking, and perhaps does so best by revealing avenues for further investigation: what exactly is it about sharing a connection point on the water infrastructure that influences advice seeking? Why does shared ethnicity matter for maize advice seeking but not for general advice seeking? In terms of policy and practice, the maize seed advice network exhibits a structure that would not lend itself well to linear information dissemination, including the overall sparseness of advice seeking and the fact that those farmers who are already practicing more on-farm climate adaptive behaviors are the ones seeking, but are not sought, for advice. Perhaps more importantly, it raises a question about who those farmers are who are not seeking advice.

7. Conclusion

Given that seed choice can be an important climate adaptive and food security resilience-enhancing mechanism for farmers, this study has sought to understand smallholder advice-seeking about maize seed varieties. The maize seed advice network is different from a general advice network in this community water project, though some drivers of ties were the same in each. Maize seed advice is a highly specific communication domain, and here, the network results characterize a particular kind of farmer who is more highly engaged in maize seeking advice and in undertaking additional climate adaptive farming practices more broadly. It may seem more likely that individuals undertaking fewer adaptive behaviors would be the ones seeking advice more often, but that is not the case here. Our results suggest that farmers are perhaps inconsistently filling for each other all the information gaps that may be left by extension or other agricultural support services. Additional research would help uncover whether advice-seeking that is specific to particular practices follows a similar pattern, which could lead to less resilient households in the long run, and has implications for social-ecological system resilience as well.

However, co-location on the irrigation infrastructure significantly shapes both the general advice network and the maize advice network. Institutions can enhance shared norms and trust (Ostrom, 1998; Ostrom and Ahn, 2003), which can facilitate climate adaptation. Considering that CWPs are not set up with the explicit goal of helping smallholders manage climate change, there is the possibility of collateral or spillover benefit for members, with the CWP helping to catalyze information sharing that helps farmers make climate adaptation choices, in this case, about maize seeds.

In terms of policy or practice, our findings inform some of the more top-down efforts by development or extension agents to share information with farmers. A typical project might find a successful farmer ("success" being measured in terms of production), target them with information or an intervention, and see how they filter out that information to other farmers. But not all farmers may be actively seeking (or open to) new information. Sharing common features with another farmer and current farming activity are better predictors of advice ties. Facilitating community discussion about the role of particular practices, such as hybrid seed use, and working to understand the flow of information specific to the practice at hand, is an essential piece of increasing adoption or allowing farmers to discover practices and technologies that fit within their farming systems, and could be more effective overall for improving livelihood outcomes in the face of climate change.

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Declaration of Competing Interest

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

Data availability

The data that has been used is confidential.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.agsy.2022.103574.

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