Homophily as a Safety Net: Investigating When Smallholder Farmers Decide to Buy Hybrid Seed in Northern Ghana

Vincent Ricciardi
Ph.D. Student, Institute for Resources, Environment and Sustainability
University of British Columbia

Abstract: Dynamic social relationships can enhance farmer adoption or lead to the rejection of modern seed varieties. Different social pathways provide farmers with information about traditional and commercial seeds. Identifying how social relationships facilitate different varietal use may reveal the informal safety nets indigenous farmers rely on when transitioning to modern varieties. While homophilous relationships have been observed to stifle farmers' adoption of agricultural innovations, these bonded social relationships are the basis for informal seed exchange. Through homophilous relationships, farmers are able to communicate pertinent risks and foster greater support systems. By examining two communities in Northern Ghana, this study tests whether homophilous relationships function as safety nets that prevent farmers from using modern seed or if they mitigate risks of agrobiodiversity decline. Through social network analysis, particular relationships were observed to act as necessary safety nets for farmers' adoption of commercial seed; whom farmers commonly interact with may protect indigenous groups from adverse risk.

Keywords: Informal seed systems, Ghana, social network analysis, agrobiodiversity, homophily

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Introduction

Since 1900, over 75 percent of crop genetic diversity has decreased with the introduction of modern varieties as farmers have transitioned to industrialized agricultural production (FAO 2012). By integrating marginal subsistence communities into global food production systems, market-oriented crop introduction tends to amplify the use of commercialized, hybrid, homogenized seeds, and consequently decreases agrobiodiversity levels (Almekinders and Elings 2001). While heightening the susceptibility of crops to blights and pests, this trend undermines the resilience of communities' food systems to globalized markets, climate change, and other emerging stressors (Bellon et al. 2011). Additionally, breeding techniques and seed distribution in the Global South often diminish the quality of commercial seed reaching subsistence-based farmers, making adoption of hybrids risky (Feder et al. 1985; Tripp and Mensah-Bonsu 2013).

Understandably, there is a pressing need to increase agricultural production and efficiency to reach the currently unprecedented number of food-insecure people (FAO 2012). A diverse seed portfolio, which includes the most complimentary combination of traditional and modern varieties for particular ecological areas, is becoming a necessary solution for subsistence farmers living in the Global South (Michelini 2013). However, there is a large debate about if hybrid crops can successfully compliment traditional varieties (Chappell and LaValle 2011; Rosset 2011). An integral component of examining quality seed access for subsistence-based agricultural populations is to address how synergies can be created between market-oriented crop introduction and agrobiodiversity conservation (Camara et al. 2005; De Boef et al. 2010). Moreover, inclusive conservation and food security interventions can be implemented by understanding when farmers choose modern varieties. Identifying how social relationships inform a farmer's choice will reveal how farmers can dually benefit from using traditional and hybrid varieties.

Dynamic social relationships can diffuse modern varieties and increase a farmer's access to traditional crops (Rogers 2003). The majority of subsistence-based farmers can continually access quality, local adapted seed, through informal seed exchanges, where farmers gift each other crop seed (Bellon et al. 2011). Using kinship, farmer groups, neighbors, and other trusted members, farmers exchange crop seed with one another to meet production needs (Almekinders and Elings 2001; Badstue et al. 2006; Pautasso et al. 2012). Increasingly, modern varieties are introduced from outside, bridging actors: plant breeders, extension workers, local markets, and development projects (Morris and Bellon 2004). Identifying why farmers decide to use modern varieties may not solely depend on what the seed is used for (e.g. drought or pest resistance), but rather if other members of the farmers' social network adopt the new technology.

Personal relationships may enhance an adoption or lead to a rejection of modern seed varieties. In order to effectively communicate the risks and benefits of commercial seed in local contexts, further detail on the social aspects of informal seed access is needed (Pautasso et al. 2012). For instance, the regional, socio-economic, and agroecological contexts can partially explain why farmers adopt or reject particular crop varieties (Brooks and Loevinsohn 2011). In part, the rate of adoption most likely is dependent on whether the variety enhances the resilience of farmers' access to quality seed and does not diminish their overall crop seed portfolio (McGuire and Sperling 2013). However, informal social networks may inhibit or facilitate the transition from farmers' sole reliance upon traditional varieties to their integrative use of modern and traditional varieties (Abay et al. 2013). Different social pathways, such as family or farmer group association, may filter information about traditional and commercial seeds received by farmers. By identifying how social relationships facilitate diverse variety use, the informal safety nets farmers rely upon when utilizing modern varieties may be revealed. This study examines the role these potential safety nets play in either preventing opportunities for integrated hybrid use or mitigating associated risks of agrobiodiversity decline.

Analytic Framework

Agricultural Innovation and Informal Seed Systems

Bonding and peer-based social relationships are the basis for farmer-to-farmer informal seed exchange (Badstue et al. 2006). Members of the same gender, kinship, age, or wealth group have a tendency to exchange information and resources more than members outside of their groups (McPherson et al. 2001; Badstue et al. 2006; Delêtre et al. 2011). These homogenous connections have been recognized as providing support, as well as ease of communication in natural resource management and have been documented in informal seed exchanges (Rao et al. 1980; Rogers 2003; Badstue et al. 2006).

Homophily is defined as the tendency of individuals to form social relationships with people who share similar characteristics with themselves (Lazarsfekd and Merton 1954). Because communication is more effective when using common, peer-based language, homophilous ties can speed up diffusion processes; the tighter the bond between individuals, the quicker information can flow (Rogers 2003; McPherson et al. 2001). These homophilous connections have been observed in informal agricultural systems: women typically trade seed with women, members of the same family gift seeds to one another for wedding celebrations and in times of need (Badstue et al. 2006), and poorer farmers introduce one another to innovative, economically viable approaches to farm management (Rogers 2003).

On the other hand, homophilous connections can also act as a barrier to the diffusion of innovations; homogenous groups tend to be insular, which prohibits novel approaches from being realized and discovered (Rogers 2003; McPherson et al. 2001; Newman and Dale 2007). Heterophilous relationships are better positioned to facilitate diffusion processes because they bridge connections between two distinct groups (Rogers 2003). Since there are different social norms from each distinct group, innovative ideas can be generated at the nexus of communication. These bridging relationships have been explained as "weak ties," where connections may introduce new concepts that act as catalyst for transformation or the introduction of an innovation. The strength of these heterogeneous ties is that new group members typically introduce ideas gained from their unique social networks; the less overlap between group members' networks, the greater access to a diversity of ideas (Granovetter 1973).

In natural resource management, heterogeneous groups typically find new, adaptive approaches that are invaluable to complex problems (Newman and Dale 2007). For example, major advances in modern crop varieties have been observed when heterogeneous groups of breeders and farmers come together to co-create locally adaptive, improved varieties to meet both the agroecological and cultural needs. These participatory plant-breeding (PPB) initiatives have higher adoption rates than traditionally bred crops because they are able to bridge breeder knowledge with farmer demands (Almekinders and Elings 2001).

Heterophilous relationships often are vertical, where certain identities may hold more social power than other members of the group (Woolcock 2000). PPB initiatives, for instance, need to take special precaution to ensure plant breeders are integrating farmer needs (Almekinders and Elings 2001). Hence, complete heterophily can result in a lack of group shared identity, which may both decrease the long-term commitment to a given problem and result in disjointed solutions (McPherson et al. 2001).

On the other hand, homophilous relationships are often horizontal, where a common shared identity can allow for higher levels of communication and camaraderie. Networks of people sharing common identities have been observed to mobilize community resources efficiently for the sustained benefit of within group members. While heterophily is essential for bridging and spreading a group's overall reach, homophily optimizes necessary resources and collaboration for within group support. Shared identity helps promote homophilous ties between farmers (McPherson et al. 2001) and serves as the social capital allowing farmers to continually access traditional varieties (Badstue et al. 2006; De Boef et al. 2010). When farmers begin to incorporate modern varieties into their seed portfolios, bridging connections will most likely inform them of modern varieties, but any potential risks may be mitigated by homophilous, horizontal relationships.

Homophily, Resilience, and Transitions

Issues surrounding homophily are emerging in debates on the resilience of environmental resource management (Newman and Dale 2007; Bodin et al. 2009; Isaacs 2012). This emergence has implications for methods farmers use to reduce their risks when including hybrids in their seed portfolios. Continual change of old, stagnant, systemic behaviors, which are collapsed, reorganized, and grown, are central to how socioecological systems continually modify themselves to build resilience against shocks and stressors (Holling and Gunderson 2002; Folke 2006). In complex socioecological systems, the identification of when systems are positioned to change and what triggers regime shifts has been significant in successful adaptive management solutions (Folke et al. 2004). Heterophilous connections aid healthy regime shifts by allowing actors to discover necessary solutions through their diverse social reaches (Bodin et al. 2006). Diverse knowledge of available tools can promote a healthy reorganization of complex systems (Folke et al. 2002; Bohensky and Maru 2011). Heterogenous connections through extension agents, agricultural input dealers, and farmer field schools may further expose farmers to modern seed.

Natural resource management projects have been observed to create more adaptive policies when there is a heterophilous group, since each member involved represents unique viewpoints with their own bridging connections. Through members' various networks, access and implementation of innovations has benefitted these projects (Newman and Dale 2007). For instance, in farmer-to-farmer advice networks on agroforestry management practices, heterophilous connections were observed to lead to more creation, adoption, and diffusion of innovative and context specific natural management practices (Isaac 2012). Furthermore, diversity of both the crops and the channels that farmers use to access seed are a key tenet in seed systems resilience (Sperling and McGuire 2013). While heterophilous connections allow farmers more diverse channels to new varieties of seed and information, they also support a repertoire of flexible responses to socioecological uncertainties (Rao et al. 1980; Rogers 2003).

Homophilous relationships, on the other hand, are often horizontal to allow fast communication channels among group members to mobilize community resources efficiently (Putnam 2000; Hill and Matsubayashi 2005). Yet, vertical relationships are commonly associated with heterophilous relationships (Woolcock 2000) and have been found to promote disconnected, immediate decisions that can become stressors within a system over time (Berke et al. 1993; Tompkins 2005; Murphy 2007).

Elements of transition management approaches echo these criticisms of heterogeneity, and provide further insight into how homophily can promote healthy regime shifts when farmers transition to using modern varieties. Transition theory explains how changes of states operate within complex systems. When particular threats are recognized, actors respond by mobilizing resources from within their community (Fischer-Kowalski and Rotmans 2009). In the context of agrobiodiversity decline, farmers who rely on traditional varieties often face threats that include inadequate yields due to climatic factors, such as erratic rainfall, drought, and shorter seasons, as well as local market price fluctuations that are tied to globalized economic trends. Incorporating modern varieties can be a solution to challenging agroecological conditions; however, hybrids can also become a threat for farmers in particular contexts where breeding standards and commercial shelf-life are dramatically affected by poor facilities, low levels of transportation infrastructure, and inefficient storage (Tripp and Mensah-Bonsu 2013). Though farmers may not be aware of these threats, the potential risks of incorporating modern varieties into their seed portfolios is only seen when others start testing hybrids (see section 2.3): “transition experiments are high-risk experiments” (Fischer-Kowalski and Rotmans 2009, 12). In transition theory, three types of threat response patterns have been identified: actors pool resources together to form a bottom-up approach, administrators provide more rigorous standards in a top-down pattern, or actors are able to respond to the threat through “squeeze paths” in a middle approach. Squeeze paths occur when individuals with sufficient homogeneous social support try to mitigate the risk through innovations. Individuals act independently to experiment with unique solutions, but are supported by their social network if the innovation fails (Fischer-Kowalski and Rotmans 2009). Once a squeeze path successfully finds novel ways to counter the threat, the path becomes easier for future farmers to navigate.

Homophilous social relationships may be the social capital individuals rely upon to test innovations. Farmers that have an effective safety net of homophilous connections - close-knit, bonded support networks that mitigate potential risks - can make up possible lost seed stores through their embedded social contracts. Additionally, farmers who are early adopters can effectively communicate pertinent information and diffuse innovations through their homophilous connections through shared common language and contexts. While heterophilous relationships are necessary for continually adaptive capacity and innovations, homophilous ties are essential for farmers who have increased risk when using modern varieties.

In transition management approaches, diversity and heterophily are essential for adaptive systems to transition from stagnant, rigid states to continual innovative responses (Geels 2005; Rotmans 2005). However, in order to create space for squeeze paths there needs to be a social environment that offers protection if the innovation fails (Fischer-Kowalski and Rotmans 2009). These transition arenas depend on innovative ideas and technologies from heterogeneous connections. New technologies can be high-risk experiments that potentially require multiple iterations when a regime transitions to a new state that incorporates the innovation.

If this transition is successful, it will become an “empowering niche” that will provide other farmers with the necessary information, knowledge, and capabilities to also make successful transitions when incorporating modern varieties into their seed portfolios (Avellino et al. 2009). Other farmers will be able to mimic and communicate with the early adopters only if they have been supported by their social exchange network and have the necessary amounts of seed. Furthermore, if the early adopters have strong bonds with other farmers, then better information about relative risks and strategies for the successful use of hybrids can be shared (Rogers 2003).

By examining farmers who are transitioning to diverse seed portfolios that include modern varieties, I hypothesize that these individuals have horizontal social support that mitigates the risks associated with hybrids; farmers need to have strong, bonded, homophilous relationships to act as a safety net in order to find successful squeeze paths where appropriate risks are enabled.

Social Seed Network Analysis

Many informal seed system studies have examined the effects of seed exchange on the evolution of particular, farmer-saved, open-pollinated crop varieties in order to explore farmers’ mitigation strategies to shocks and stressors of traditional variety loss (e.g. Pandey et al. 2011; Vom Brocke et al. 2003). For instance, if a farmer loses their seed stores due to rot or insect damage, the farmer can ask their social network for seed; commonly, this exchange will not cost the farmer money, rather the payment may include providing labor, food, or seed at a later date. Social network analysis has recently been applied to informal seed exchanges (Subedi et al. 2003; Abay et al. 2011; Pautasso et al. 2012). Nonetheless, it has already provided important groundwork to create more effective micro policies that promote agrobiodiversity conservation and effective improved crop adoption (Gupta and Vikas 2010; Abay et al. 2011).

Only a few studies have used social network analysis to focus on strategies that strengthen human dimensions of informal seed systems, such as connecting *in situ* and *ex situ* conservation methods (e.g. connecting community-based conservation projects with local seed banks) (Subedi et al. 2003; Abay et al. 2011). Subedi et al. (2003) observed how twenty-five different rice varieties in Nepal were traded across several villages and found that relative trading distance mattered more than kinship in predicting seed exchange partners. Abay et al. (2011) coined the term "social seed network analysis" when they identified several network centrality measures to monitor seed and variety flows in informal seed systems.

These studies have utilized the capabilities of social seed network analysis to provide detailed mapping of informal seed systems. However, more research applications of social seed network analysis are needed to strengthen informal seed systems. For instance, social seed network analysis should also be used to examine the intersection of traditional and hybrid seed usage. Social seed network analysis can measure homophily and the roles different farmers assume within their community to ensure their own continual seed access. The various social relationships of farmers may prevent opportunities for integrated use of hybrids or reveal safety nets to mitigate the associated risks of agrobiodiversity decline.

Methodology

Site Description

Data was collected June 2013 in two subsistence-farming communities, Aduyuli and Diani; these remote rural communities are located in West Mamprusi and Tolon-Kumbungu districts, respectively, in the Northern Region of Ghana. In these communities, subsistence-based agriculture with minimal small-scale commercial agriculture is the predominant livelihood strategy. This region is among the most food insecure and poverty-stricken areas of Ghana (Whitehead 2006). Complicated communal land tenure issues favor males, encourage farm fragmentation, and promote the use of land as collateral security for bank loans (Peters 2004). Likewise, limited resource environments are exacerbated by the region's sub-humid to semi-arid Guinea and Sudan savannah, where farmers rely on rain-fed irrigation (Gyasi 1994). Major staple crops that are frequently exchanged in both villages are groundnut (*Arachis hypogaea)*, cassava (*Manihot esculenta)*, maize (*Zea mays)*, millet (*Panicum miliaceum)*, rice (*Oryza glaberrima)*, sorghum (*Sorghum guineense)*, sweet potato (*Ipomoea batatas)*, and yam (*Dioscorea rotundata*). Beans and garden vegetables were grouped into general categories in this study due to the infrequency of trade mentioned.

Data Collection

Surveys were administered at the household level. Aduyuli contained forty-nine households, of which thirty-three were interviewed; each household had an average of fifteen immediate and extended cohabitating family members. Diani contained sixty-two households, of which thirty-four were interviewed; each household had an average of seventeen immediate and extended cohabitating family members. Only one interview was conducted at each household, as within the household high fluidity of shared resources was observed. Initially, six individuals were interviewed, selected via a stratified snowball sample based on relative local wealth and gender. Subsequent participants were identified when listed by the previously interviewed farmers as seed-exchanging partners. Relative local wealth was classified for each household using participatory rural appraisal (PRA) techniques. Small focus groups of key informants used a community wealth ranking technique to determine low, medium, or high wealth for each household (Rifkin 1996). Together, participants, translators, and I determined guiding criteria to rank each household into wealth categories: land holdings, motorbike ownership, non-agriculturally based employment, relatives from outside the community who send back money, and several other factors.

Through four enumerators, a mixed closed and open response questionnaire was conducted in the local languages, Mamprusi and Dagbani. The survey's aim was to identify seed exchange partners and to capture information about farmers' agricultural activities relating to crop seed use. Famers were asked with whom they traded seed according to the name-generator technique (Marsden 2004). Through several probing questions, farmers identified between five to fifteen crop-specific trading partners. Key sociodemographic information was obtained for both the interviewee and their trading partners.

From the survey, ten dichotomous, directional, N x N adjacency matrices (where actor *i* gives seed to actor *j*) were generated for each crop that farmers identified. The ties represent farmer-to-farmer crop seed exchanges. Each cell in the matrices represents if farmer *i* gave seed to farmer *j*. If they gave or did not give seed the cell was dichotomously coded as either "1" or "0," respectively. These ten adjacency matrices were summed into one weighted, directional matrix. For example, in the summed matrix, if farmer *i* gave seed to farmer *j* for only one of the ten crops, then their shared cell (*i*,*j*) received a "1," however, if they traded seed for two of the ten crops their shared cell (*i*,*j*) received a "2."

Anecdotally, farmers spoke of obtaining new varieties and crop types from farmers with whom they already had established relationships. Hence, by combining all crop seed exchanges, a more accurate portrayal of the farmers' entire exchange network can be illustrated. Each community represented the network boundaries; there was no trade captured outside of each community as to eliminate potential broken network effects. This boundary was determined by the scope of this study and by insight from past social seed network studies that showed most seed exchange occurred within distinct communities (Subedi et al 2003; Abay et al. 2013).

Variables of Interest

Several variables of individual characteristics of farmers and characteristics of their social networks were identified from the questionnaire to capture potential homophilous trading relationships, such as, gender, age, kinship, and relative wealth. These individual-level characteristics incorporate both status homophily - where attributes are ascribed based on outward status, such as age, gender, or relative wealth – and value homophily - where values, attitudes, and beliefs form relationships, such as kinship identification, and trust formation (Lazaersfeld and Merton 1954; McPherson et al. 2001).

Gender has been cited in informal seed systems as a vital component to both crop exchanges as well as the primary tasks associated with seed-saving related activities (Subedi et al. 2003; Badstue et al. 2006; Gill et al. 2013). Gender was coded as "1" female, "0" male. A categorical age variable was coded as "youngest" (under thirty-five years old), "middle" (between thirty-five and fifty-five years old), and "oldest" (above fifty-five years old), according to the standard deviation of the sample. Farmers were asked to identify their relationship with their exchange partners (e.g. neighbors, acquaintances, strangers, extended family, or close friends); due to the abundance of responses indicating extended family, relationship was later recoded into a dummy variable "kinship." "Average kinship" is a variable that takes the average relationship between a farmer and all their exchange partners. Relative wealth has been associated with different levels of agrobiodiversity. Lower wealth farmers typically rely on the informal seed exchanges of traditional crops and have more farmer variety agrobiodiversity, while wealthier farmers are able to purchase modern, homogenized, commercial varieties (Lipper et al. 2005). Based on the community wealth rankings, farmers' households were broken categorically into "low," "medium," and "high." Farmers were asked about modern variety use in the previous cropping season because most farmers were not certain of their trading partners' use of commercial seeds. While there were an abundance of different commercial crops purchased, modern variety use was coded dichotomously to capture farmers' general use of hybrids.

Analysis

To test if homophilous connections provide a safety net for farmers to risk using modern varieties of seed, two hypotheses were tested: firstly, the willingness and capability of farmers to connect over shared demographic characteristics allows for stronger connections that mitigate the risks of adopting modern varieties; secondly, though heterophilous connections are essential to farmer access to modern seed varieties, homophilous connections are a necessary component in a socially supported, diverse seed portfolio.

Homophily was measured in several steps. First, a metric is calculated to indicate homophily levels for certain groups (e.g. gender, age, wealth, etc.). This metric illustrates how groups operate on a whole, not how the subgroups (e.g. females or males, high or low wealth) act on their own. The purpose of this broad calculation is to assess how group members generally trade with other farmers sharing similar characteristics. To calculate this metric the "homophily" routine in the social network analysis software package UCINET was used (Borgatti et al. 2002). This routine uses an E-I index to indicate homophily. If the group has a score of -1 each subgroup has pure homophily where farmers only trade seed with members of their own subgroup. If the group has a score of +1 each subgroup has pure heterophily, where farmers only trade seed with members not of their group. The E-I index (shown below) is calculated by first taking the total number of weighted ties external to the group minus the total number of weighted ties internal to the group, then divided by the total number of weighted ties averaged across communities (Krackhardt and Stern 1998; Isaacs 2012):

E-I index = (# trades external to group - # trades internal to group)/total # ties

The score provided is for the group as a whole (e.g. gender, age, wealth, etc.), not for each subgroup (e.g. females or males, low or high wealth). Assessing which subgroup shows the highest homophily scores is critical to determining if there are subgroup differences in the amount of modern varieties each subgroup bought. The measure of subgroup differences was captured during UCINET's "Homophily" routine as raw counts that were later transformed into percentages. The percent a subgroup has when trading within their subgrouping indicates the percentage of homophilous trade -- the higher this percentage is, the higher the homophilous trade.

My hypothesis relies on these homophily percentages. If hybrid seed use is associated with higher homophily scores, then this suggests that the homophilous groups act as a necessary safety net for farmers to mitigate risk of using modern varieties. Conversely, if hybrid seed use is associated with lower homophily scores, then this suggests that farmers do not rely on homophilous relationships for a safety net.

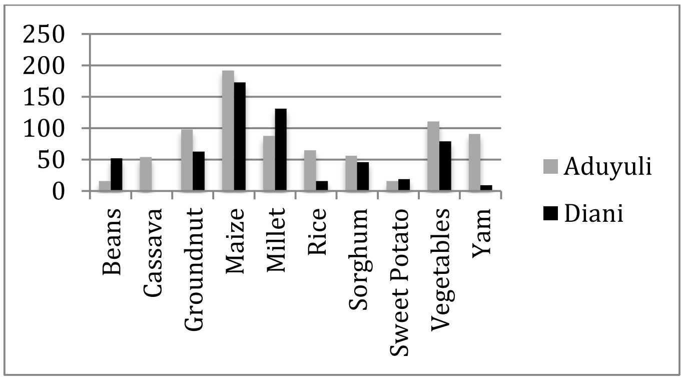
Since each community had relatively few farmers who were beginning to use modern varieties, no statistical tests were conducted. Only eighteen Aduyuli farmers captured in the survey sample used modern varieties last year, while twelve farmers were counted in Diani that used modern varieties. While raw counts and percentages can reveal potential trends, this analysis captures the beginning of Ghanaian farmer modern variety use in both communities.

Results

Descriptive Findings

Both Aduyuli and Diani share similar amounts of seed exchange for each crop. Maize seed is the most frequently traded crop type, on average being traded 182 times in my sample over the last 12 years, while sweet potato vines were traded only 17 times (Figure 1). This difference may relate to both the amount of maize planted in the community and the difficulty in effectively handling sweet potato vines. Cereal crops in general are more frequently traded than tubers; however, there is a moderate amount of garden vegetables traded in both communities.

Figure 1. Number of crop exchanges by variety



The two communities shared several similarities in descriptive sample characteristics, such as gender, and age (Table 1). There were more farmers between forty-one and forty-four years old in both communities. There was significant variability in the wealth rankings between communities for low and medium wealth, but the wealth ranking was relatively consistent for wealthy farmers. Diani had a more even distribution of wealth than Aduyuli, which had 48 percent of households classified as low wealth. One explanation for this is that Aduyuli is farther away from both the capital of the Northern Region, Tamale, and the main headquarters for the national extension and agricultural research stations. Diani is only 18 kilometers away from Tamale, while Aduyuli is 130 kilometers away. Not only does this influence off-farm work opportunities, but also extension and development project involvement. The descriptive statistics also show noticeable differences in farmer preference to exchange seed within their kinship group and the average longevity of trading relationships in each community. Aduyuli's remoteness may account for the stronger kinship preference because there is less outmigration than in Diani.

Table 1. Descriptive statistics

	Communities Combined			Modern Varieties		
	N	Mean	St. Dev.	Aduyuli	Diani	Total(%)
Gender						
Females	245	0.38	0.49	4	3	0.24
Males				14	8	0.76
Kinship						
Witnin Kin	245	0.74	0.44	13	7	0.67
Non-Kin				5	5	0.33
Age						
Under 35 Years Old	245	0.31	0.47	5	5	0.33
Between 35 to 55	245	0.46	0.50	9	3	0.4
Over 55 Years Old	245	0.22	0.42	4	4	0.27
Wealth						
Low Wealth	245	0.39	0.49	7	3	0.33
Middle Wealth	245	0.27	0.45	5	4	0.3
High Wealth	245	0.34	0.47	6	5	0.36

Modern Variety Use

The amount and type of modern varieties used in each community were relatively similar. Only eighteen Aduyuli farmers captured in the survey sample used modern varieties in 2012, while twelve Diani farmers used modern varieties. Commercial hybrid maize (*Zea mays*) seed accounted for half of all modern seed purchases in both communities; the remainder of all seed purchases consisted of sorghum (*Sorghum guineense*), groundnut (*Arachis hypogaea*), and cowpeas (*Vigna unguiculata*). These seed purchases in Aduyuli and Diani are consistent with the top six most prevalent commercial seed varieties available in Ghana, excluding rice and soybeans (Tripp and Mensah-Bonsu 2013), which were not grown by farmers in this sample. Across communities, 31 percent of farmers interviewed purchased commercial varieties last year; this percentage exceeds the International Food Policy Research Institute (IFPRI) 2009 estimates that similar, rural periphery communities worldwide were expected to rely on 20 percent commercial seed out of their portfolios (Smale et al. 2009).

The raw counts of modern variety use reveal key differences among subgroups. Accounting for 76 percent of modern variety use, males typically purchased more modern varieties across communities than females. Males used hybrid maize, sorghum, and groundnut most prevalently, while females reported using hybrid cowpea varieties. Across both communities, the highest exchange rates of cowpeas were between females rather than men. These findings are consistent with other studies (Vander Mey 1999; Padmanabhan 2002), as cowpeas have been well documented throughout West Africa as being cultivated, processed, and sold by females (Otoo et al. 2011; Padmanabhan 2002). Conversely, while maize has been documented in Ghana as a crop used by both genders, the rate of adoption in hybrid maize seed use is considerably higher for males than females (Doss and Moris 2000). Among wealth categories, agents revealed no differences in general and crop-specific use of modern varieties. Each wealth category had an average of 33 percent of the sample using modern seed. However, each other group showed marked differences between their own subgroups. Middle-aged farmers used more modern varieties (40 percent) across communities than farmers of other age categories. The oldest group was more likely to have longer trading relationships than other age groups and was less likely to use modern varieties. Farmers who typically trade within their kinship group accounted for 67 percent of the modern variety use.

Homophily Versus Heterophily

The E-I index was used to measure if the subgroups were typically part of homophilous or heterophilous trade relationships. Gender and kinship were the only E-I index scores indicating homophily for an entire group in both communities (Table 2). Female-to-female trade was the most prevalent trading type within this group across both communities (66.5 percent).

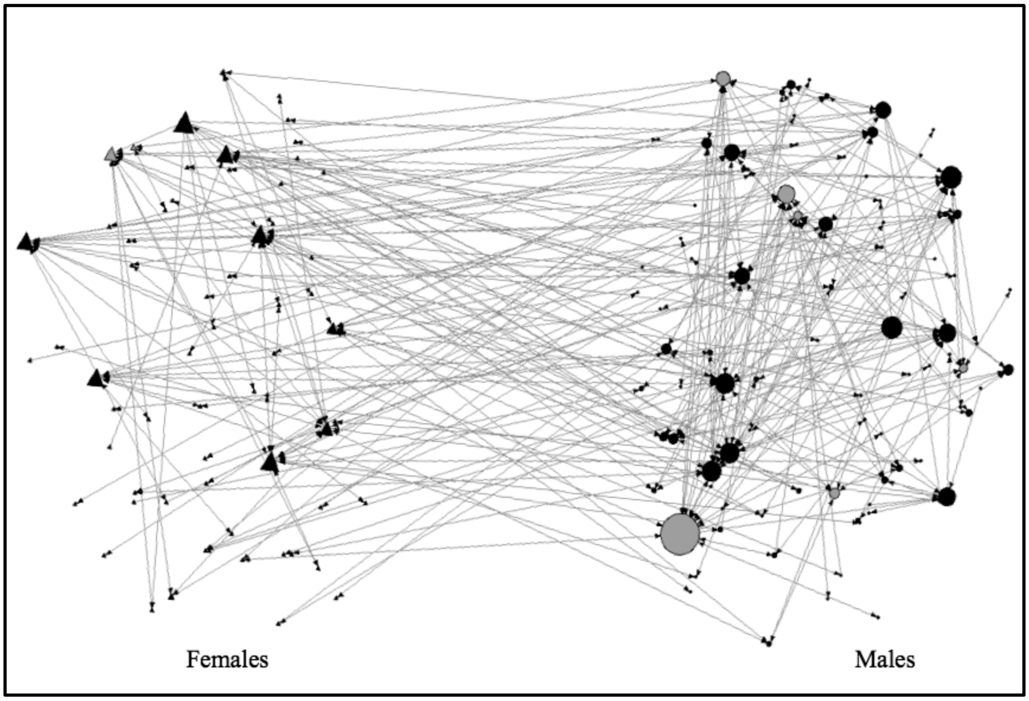
Table 2. Trade relationships

	E-I Index	Percent Trade Among Groups			
Gender	-0.1175				
			Females	Males	
		Females	66.48	33.52	
		Males	65.67	34.33	
Kinship	-0.1021				
			Kinship	Non-Kin	
		Kinship	70.92	29.08	
		Non-Kin	73.77	26.23	
Age	0.2118				
			Youngest	Middle	Oldest
		Youngest	41.46	40.12	18.43
		Middle	31.28	45.23	23.49
		Oldest	29.67	44.25	26.09
Wealth	0.1968				
			Lowest	Middle	Highest
		Low	46.21	15.01	38.78
		Middle	33.53	37.03	29.45
		High	47.09	17.48	35.43

Conversely, men engaged in homophilous trade in 34.3 percent of exchanges and gave seeds to women 65.7 percent of the time. Hence, seed exchanged was predominantly through female networks. Figure 2 is a sociogram, a visual network representation, of gendered seed exchanges in Aduyuli. Each gender (females are represented by triangles and males are represented by circles) is set apart to visualize both within group, homophilous connections, and between group, heterophilous connections. The grey nodes are farmers that purchased modern varieties during the previous cropping season and the black are farmers who rely solely on traditional varieties.

Figure 2. Gendered modern variety use

Each tie represents a crop seed exchanged between two farmers. The triangles represent female farmers, while the circles represent male farmers. The black nodes represent farmers who do not use any modern seed varieties, while the gray nodes indicate modern variety use. Note: farmers who use modern varieties tend to use a mix of modern and traditional seed.



While consistent with prior studies that indicate most seed saving and trading activity are female driven, this result is actually counter to my hypothesis. Although there is higher homophilous female-to-female trade, modern varieties are primarily used by male farmers. Strong within group trade among female farmers of traditional crops and the limited use of modern varieties suggest that homophily prevents females from accessing diverse channels of seed access. Past studies indicate significant gender differences in agricultural innovation adoption in Ghana due to limited market access, lack of information, and gendered tasks (Doss and Morris 2000).

While gender homophily may account for this disparity in modern seed access, kinship homophily corresponds with greater use of modern varieties. Across communities, the E-I Index score of -0.10 indicates moderate rates of homophilous trade between family members. Sixty-seven percent of farmers that rely on kin-to-kin trade use modern varieties. While the small sample has limited statistical power, raw numbers suggest a correlation between farmers depending on kinship alliances and hybrid seed use. These results are consistent with previous studies that observed high levels of intra-family seed exchange that replenish seed supply when yields are insufficient (Townsend 1994; Badstue et al. 2006). Kinship homophily supplies farmers with seed when testing hybrids produces inadequate yields. Through strong kinship alliances, farmers can be supported by their trade partners when integrating modern varieties. Kinship homophily appears to act as an informal safety net when farmers across communities choose to incorporate modern varieties. Furthermore, farmers' developments of squeeze paths to diverse seed portfolios are supported by homophilous kinship connections. In these ways, family alliances provide the necessary social support for farmers to mitigate the risks of using modern varieties in this context.

Although, the overall E-I index score of age groups indicates heterophilous trade, there are certain subgroups that rely on homophilous connections. The most prevalent homophilous trade within age subgroups was between middle-age farmers. The middle-age group used the majority of all modern varieties at 40 percent and was the most homophilous with 45.23 percent of middle-age farmers exchanging seed with other middle-age farmers. Notably, all other age groups typically gave seed to middle-age farmers; the amount of homophilous and cross-age support for the middle-age group was greater than any other age group. There is a connection between this within and between group support and middle-age farmers' ability to manage the risk of transitioning to hybrid seed.

Middle-age farmers were in a unique position that expands my hypothesis. Both homophilous trade and heterophilous support were available to provide safety nets to farmers in the middle-age group. Aging populations have been observed to rely on younger generations to mitigate their future risks by accessing resources or new information (Uhlenberg and Gierveld 2004). Additionally, younger populations may not have built their support networks to a level that they can mitigate risking inadequate yields, even though most social bonding occurs at younger ages (Fafchamps 2008). The middle-age group has ample safety nets to integrate risks into their seed portfolios because of homophily and their unique position, which bridges age groups.

Wealth group seed exchange acted similarly to age-based exchange; however, the homophilous subgroups did not predominantly purchase more modern varieties. Low wealth-to-low wealth seed exchange was the most homophilous group and received ample amounts of seed from other wealth categories. However, unlike the middle-age subgroup, the heterophilous and homophilous support given to low wealth farmers did not result in more hybrid seed purchases. There was no difference in the amount of modern varieties each wealth subgroup used across communities; on average subgroups used 34 percent hybrids. This observation can be explained in two ways. First, low wealth farmers were unwilling to accept lower yields because they cannot absorb the risk even with heterophilous social support. Past research supports this view. Dercon (2002) finds that in rural Tanzania lower wealth farmers had the least diverse income generating channels and significantly smaller diversification of crop portfolios. Another explanation is that low wealth farmers are more vulnerable than other wealth groups; hence, the amount of modern varieties they use compared to their relative risk may be far greater than wealthier farmers. Low wealth farmers only were able to seek diversified seed portfolios of similar levels to other wealth groups with heterophilous and homophilous support. The different relative risks between subgroups suggest that wealthier farmers presumably need less support than low wealth farmers to incorporate hybrids.

Discussion

This study found that certain homophilous relationships influence when farmers begin to use commercial seed. For instance, the type of relationship and the groups' status in the community may indicate in what ways homophily or heterophily facilitate farmers' use of modern varieties. Several trends were observed to support my hypothesis that homophily may act as a necessary safety net for farmers' ability to incorporate modern varieties to further diversify their seed portfolios. Farmers with greater trade around shared kinship relations and farmers who exchanged with other middle-age peers, tried modern varieties more frequently. The high amount of kinship-based trades has been well documented (Badstue et al 2006), but this study shows that greater kinship homophily is associated with increased modern variety use. Middle-age trade relationships exhibited similar patterns, where farmers were supported by homophilous connections of other middle-age farmers to test modern varieties. The common homophilous trade patterns within these groups, fostered by shared experiences and common language, seemed to allow farmers to risk incorporating modern varieties into their seed portfolios.

However, wealth categories and gender did not support my hypothesis, which suggests that particular types of social relationships influence farmers to take risks more than homophily alone. Overall, males and high wealth farmers possessed the most heterophilous relationships and purchased the greatest number of modern varieties. Gendered trade and purchases of agricultural inputs in Ghana is consistent with other studies (Doss and Morris 2001). For wealth and gender based homophily, I observed a stifling effect on farmers' utilization of hybrids. This effect is consistent with past natural management studies where homogenous pathways to innovations offer less diffusion of innovations (Rogers 2003; Newman and Dale 2007). Because females and low wealth groups are among the most vulnerable in these communities where land holdings are governed primarily by males and wealthier families (Gyasi 1994; Peters 2004), the attempt to use modern varieties may be a larger risk to the livelihood of females and low wealth groups. In both Aduyuli and Diani, male farmers held community positions that interfaced them with agricultural companies and/or agricultural extension offices. There were no female farmers established in these roles, and men who had more family ties seemed to be able to leverage their social network to sit in these positions. Since these two communities relied heavily on subsistence-surplus agriculture, the farmers with community positions connecting them to agricultural companies and extension agencies were exposed to more information and could access more resources than other farmers. Hence, it is not surprising that males and farmers that had more kinship connections were the two groups that used more modern varieties.

Even for these well connected male farmers, farmer information in rural Ghana has primarily been shared through agricultural input dealers, who can over emphasize the benefits of hybrids and fertilizers to consumers due to their market-based agenda. Lack of educational opportunities has also led to minimal adoption and insufficient yields (Akudugu et al. 2012). In Aduyuli and Diani there was minimal to no post-primary education, and limited access to extension agents, workshops, or farmer-field schools. The available social channels present potential misinformation about hybrids. There is an identified need for extension services to transition from high-input recommendations for inorganic fertilizers to providing farmers the necessary information and skills to optimize synergy between traditional and hybrid varieties (Snapp et al. 2003).

The transition to using modern varieties can be risky, especially in the Ghanaian context where hybrid breeding and commercial shelf-life can cause variability in quality of seed (Tripp and Mensah-Bonsu 2013). However, there may be a tipping point where homophilous connections act as a shield to vulnerable groups' adopting risky innovations. In this sense, homophilous groups' insular nature protects them from adverse change. The most vulnerable groups may not be stifled by homophily, but may actually prefer to rely on their bonded connections for continual access to locally adapted, high quality seed that they trust will grow well. Homophilous connections are not supportive niches for these groups to incorporate innovations, but rather are necessary components of farmers' sustained seed access. Finding squeeze paths is more difficult for these vulnerable groups because the seed exchange partners they depend on cannot provide adequate support. Since transitions include risky experimentation by squeeze path pioneers (Fischer-Kowalski and Rotmans 2009), vulnerable groups need to group together more tightly than other groups to ensure adequate social support. The reliance of certain groups on horizontal relationships may be invaluable insulation from potentially risky change and promote squeeze path pioneers.

This study's results suggest that a broadened understanding of how homophilous relationships function in adaptive natural management systems is needed. Newman and Dale (2007) observed that heterophilous relationships were critical to accessing a diverse array of resources. However, only some forms of heterophilous connections facilitated diverse channels of seed access. If a squeeze path pioneer makes a successful transition to integrating hybrids, then they provide other farmers with the necessary information, knowledge, and capabilities to also make successful transitions when incorporating modern varieties into their seed portfolios (Avelino et al. 2009). If enough farmers are able to follow the established squeeze path, then an "empowering niche" is developed where farmers are supporting one another successfully to further diversify their seed portfolios. Yet, the vertical nature of heterophilous relationships often are top-down structures, hence if the initial squeeze path pioneer is from a different socio-economic group than later adopters, the more vulnerable types of farmers may face risks not yet encountered. This top down structure was present in this study, where the higher and lower wealth farmers exchanged with one another while the middle income farmers had homophilous dominated trades; both the high and low income groups purchased hybrids more often than middle income farmers. Since farmers will mimic and communicate with the early adopters (Rogers 2003), if they are not supported by their peers, then the same solutions for squeeze path pioneers may need to be adapted to meet vulnerable groups' needs. While homophilous connections alone cannot explain when farmers shift to use modern varieties, peer-based communication is essential to pertinent information exchange about how these groups can adapt the initial squeeze paths to meet their needs. The ease of communication and horizontal structure of homophilous relationships is a critical component that should be considered when formulating natural resource management groups.

This study had several limitations, which include sampling from only two communities, testing seed exchange relationships instead of other types of farmer advice networks, and limited demographic variables were collected. Future research should examine how farmer advice networks influence modern variety use or even other forms of modern agricultural technology; farmers may solicit advice from others who are outside of their seed exchange and kinship networks. Additionally, future research should test if reducing seed exchanges is affected by increased hybrid use and test if this affects farmers' ability to access traditional seed. Finally, for vulnerable groups, homophily may act as a mechanism for agrobiodiversity conservation because they primarily rely on traditional crops; understanding which homophilous connections act as informal safety nets may provide greater understanding when farmers transition to using commercial seed.

Conclusion

In farmer adoption of modern varieties and natural resource management, more attention needs to be given to the levels and types of homophilous and heterophilous relationships more broadly. The choice of social relationships farmers use to incorporate a diversity of traditional and modern varieties can make them resilient (Sperling and McGuire 2013) only if they have proper safety nets to mitigate potential risks. While bridging connections can lead to better access to innovations, bonding relationships can be more effective at communicating pertinent information (McPherson et al. 2001) for certain groups of farmers. Where and when farmers choose to make synergy between traditional and modern varieties depends upon the balance between bridging and bonding ties. Understanding when farmers choose to take risks can lead to a clearer idea of how social relationships provide safety nets that promote diverse seed access.

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