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Contrasting innovation networks in smallholder agricultural producer cooperatives: Insights from the Niayes Region of Senegal

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ABSTRACT

Despite growing support for agricultural cooperatives as mechanisms for rural development, relatively little is known about how innovation spreads through, or is created within, the formal structure of a cooperative. This paper provides an 'inside' look at the social relationships operating within two agricultural cooperatives in rural Senegal (one well-functioning and the other poorly-functioning), focusing on self-reported innovation sharing and provisioning between members. Findings indicate that for both cooperatives, innovation was predominantly spread through formal vertical linkages (i.e. between hierarchical representatives), but was significantly controlled by key actors in leadership positions, resulting in large disparities in the innovation potential of different cooperative members. Social Network Analysis can help inform the design and evaluation of agricultural cooperatives by shifting the analysis to individual actors within the formal structure, potentially enabling new opportunities for enhanced cooperation to be identified and collectively strengthened.

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1. Introduction

Increasingly, farmers, policymakers, academics, and donors have been identifying agricultural cooperatives as essential institutional vehicles to facilitate information exchange, improve collaboration, innovation, and market access for smallholder farmers (Bernard & Spielman, 2009; Fischer & Qaim, 2012). As a result, cooperatives have been receiving increased financial and other support from development and government agencies to facilitate agricultural system innovation and poverty alleviation (Johnson & Shaw, 2014). On the African continent, cooperatives have been experiencing a revival on both theoretical and practical grounds; following decades of often inefficient and unsustainable practices by colonial and post-independence governments (see Deininger, 1995; Swinnen & Maertens, 2007). According to Develtere, Pollet, and Wanyama, 2008, approximately one in seven Africans now belong to a cooperative, with countries such as Senegal, Rwanda, and Egypt possessing membership rates of over ten percent. These 'contemporary' cooperatives have been reported to benefit smallholders economically by reducing transaction costs, increasing market access, and improving bargaining power (Bernard &

Taffesse, 2012). For example, Markelova and Mwangi (2009) argued that by harnessing collective action, cooperatives could help smallholder farmers aggregate their surplus output, pool both tangible and intangible resources, generate economies of scale and scope in marketing, and strengthen their bargaining position to improve their place in the market (Blokland & Gouët, 2007; Collion & Rondot, 1998). Further, agricultural cooperatives can simplify marketing and values by directly bypassing intermediaries and lowering horizontal and vertical coordination costs (Shiferaw, Okello, & Reddy, 2009). However, despite the broad international support, academic research on cooperatives has revealed both failures (see Hill, Bernard, & Dewina, 2008) and successes (see Bernard, Taffesse, & Gabre-Madhin, 2008; Okello, Narrod, & Roy, 2011), raising questions concerning their ability to facilitate positive and sustainable innovation amongst their members.

Agricultural system innovation involves bringing new ideas, practices, or processes into diverse smallholder farming systems (Klerkx et al., 2011; Spielman, Davis, Negash, & Ayele, 2011). Such systems "consist of a wide range of actors from the public, private, and civil sector to bring new products, new processes, and new forms of organization into economic use, together with the institutions and policies that affect the way different agents interact, share, access, and exchange and use knowledge" (World Bank, 2008). In this context, agricultural innovation is not only concerned with new technologies, but also with alternative ways of organizing: including

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institutions, markets, labour, gender relations, and the distribution of benefits (Leeuwis & Ban, 2004) in order to facilitate joint learning, create new institutional arrangements and practices (Klerkx, Hall, & Leeuwis, 2009; Sumberg, 2005; van Rijn, Bulte, & Adekunle, 2012). Although agricultural innovation studies at the regional and national levels are fairly numerous (for example: Borda-Rodriguez & Vicari, 2014; Saint Ville, Hickey, & Phillip, 2015), relatively few have addressed the smallholder innovation system at its most basic level – the producers. Examples in Sub-Saharan Africa include Spielman et al. (2011) who examined how social networks facilitate the transfer of knowledge between Ethiopian smallholders, and Raini, Zebitz and Hoffmann (2006) who used social network analysis as a tool to detect disparities in information flows among key agricultural actors in Kenya in the development of integrated pest management techniques for tomato cultivation, as well as others such as Hermans et al. (2013). With some exceptions (see Douthwaite, Carvajal, Alvarez, Claros, & Hernández, 2006), few of these studies have focused specifically on how innovation spreads within formal institutional structures, such as agricultural producer cooperatives. In this context, cooperatives have been identified as contributing to the innovation potential of smallholder farmers by: linking and bridging external actors (Clark, 2002; Gouet & Van Paassen, 2012), articulating technological needs and demands for skills (Kilelu, Klerkx, Leeuwis, & Hall, 2011), and creating and supporting new knowledge (Hall & Clark, 2010).

Within this discourse, an important knowledge gap relates to the activities of individual actors within agricultural co-operatives (members) and their relative roles in facilitating innovation (Markard & Truffer, 2008). Further, while a number of studies have reported the positive impacts of cooperative membership using economic indicators, including farm income, farm profits, technological adoption, and market participation (see Fischer & Qaim, 2012; Francesconi & Heerinck, 2010; Shiferaw et al., 2009), few have focused on the social dimension of cooperatives, including the distribution of benefits, social networks, and power hierarchies (Develtere, 1994). In particular, social networks are known to be essential for smallholders to access agricultural information and innovations (van Rijn et al., 2012), to manage risk and vulnerability (Woolcock & Narayan, 2000), and build adaptive capacity to withstand external shocks (Brown & Westaway, 2011). Previous research focusing on the social dimension of agricultural co-operatives has generally identified that social networks are either: a) the product or outcome of functioning cooperatives (see Majee & Hoyt, 2011; Majee, 2007; Richards & Reed, 2015); or b) a contributing factor to the re-popularization of cooperatives (see Myers, 2004). However, recent research has focused more on the external organizational linkages of co-operatives in the context of innovation (Novkovic & Holm, 2012), poverty reduction (Simmons & Birchall, 2008), and economic cooperation (Muthuma, 2011; Valentinov, 2004), but significantly less on the internal social networks and relationships operating within and underpinning cooperatives. Recognizing the importance of this knowledge gap, we sought to explore how the internal social organizational structure of cooperatives can influence their ability to spread agricultural innovation, focusing on two smallholder agricultural cooperatives operating in rural Senegal.

In what follows we provide a brief historical description of the cooperative movement in Senegal. We then outline our research methods, followed by detailed results and a discussion of their significance for research, policy and practice.

2. A brief history of agricultural cooperatives in Senegal

Agriculture is an important sector of Senegal's economy, employing approximately 73% of the population and comprising

16.6% of national GDP in 2013 (CNCR, 2014). Smallholders, who make up approximately 95% of the agriculture sector in Senegal, are primarily organized into producer cooperatives, which have experienced a tumultuous history over the last four decades (Republique of Senegal, 2014). The French colonial tradition of '*sociétés indigènes de prévoyance*' imposed centrally-organized cooperatives on Senegalese smallholders in order to support the growing of cotton and peanuts for export markets (CNCR, 2014; Johnson & Shaw, 2014). The first leaders of independent Senegal, Prime Minister Dia and President Senghor, believed that the cooperative movement would transform Senegalese politics into a self-managing socialism (Fall, 2008). However, this vision was not realized, with cooperatives instead becoming state-led and externally imposed (Sylla, 2006). In the period following independence (1960–1984), the government controlled, supervised, and distributed agricultural inputs and managed the marketing, storage and sale of farmer's production, leaving smallholders primarily responsible for cultivation (CNCR, 2014). In 1984, a radical change occurred in Senegal's cooperative system through the imposition of structural adjustment policies by the World Bank (Fall, 2008). The subsequent New Agricultural Policy (*Nouvelle Politique Agricole*) in 1984 brought economic liberalisation and the introduction of an Economic Interest Group (GIE), effectively eliminating the state's role in agriculture and ostracizing many smallholders and their livelihoods (Cissokho, 2008). Despite the state's withdrawal, a number of historical legacies have led to what Gellar (2005) argued as being "...unsuitable organizational modes, governance rules, and regulations" placed on rural associations, which have generally been seen as impeding smallholders' innovation capacity.

More recently, the cooperative movement in Senegal has experienced a revival in both national and regional policy frameworks. At the national level, the introduction of the Agro-Sylvo Pastoral Law in 2009 provided both legal and financial support for agricultural professionals to organize, strengthening agricultural cooperatives. Furthermore, the recent amendment and adoption of the Policy for Cooperatives in 2010 (*Politique de développement coopérative*) has provided an important update to the previous 1984 Cooperative Law. Regionally, the Senegalese government has also supported negotiations with the Uniform Act related to the Rights of Cooperative Societies of 2010 (*Acte Uniforme Relatif au Droit des Sociétés Coopératives*) held by the Organization for the Harmonization of Business Law in Africa, in order to help bolster cooperatives in the West African region.

3. Methods

Working within a multiple-case study research design (Creswell, 2013; Yin, 2003), we drew on both qualitative and quantitative methods to explore the role of social networks in agricultural cooperatives (and more specifically, their impact upon self-reported innovation and cooperative performance). Adopting a mixed-methods approach to data collection and analysis allowed us to increase the reliability of our findings through recursive data triangulation and methodological overlap (Harwell, 2011).

3.1. Study setting and case selection

On the western coast of Senegal lies a vital agro-ecological and economic region known as the Niayes (Fig. 1). The region is home to approximately 52% of the Senegalese population and produces up to 80% of Dakar's fresh agricultural produce (Dasylyva, 2012; Touré & Seck, 2005). The predominant economic activity is horticulture production, with approximately 98% of this controlled by smallholder farmers (CNCR, 2014). As with other parts of Senegal, smallholders in the Niayes region face a wide range

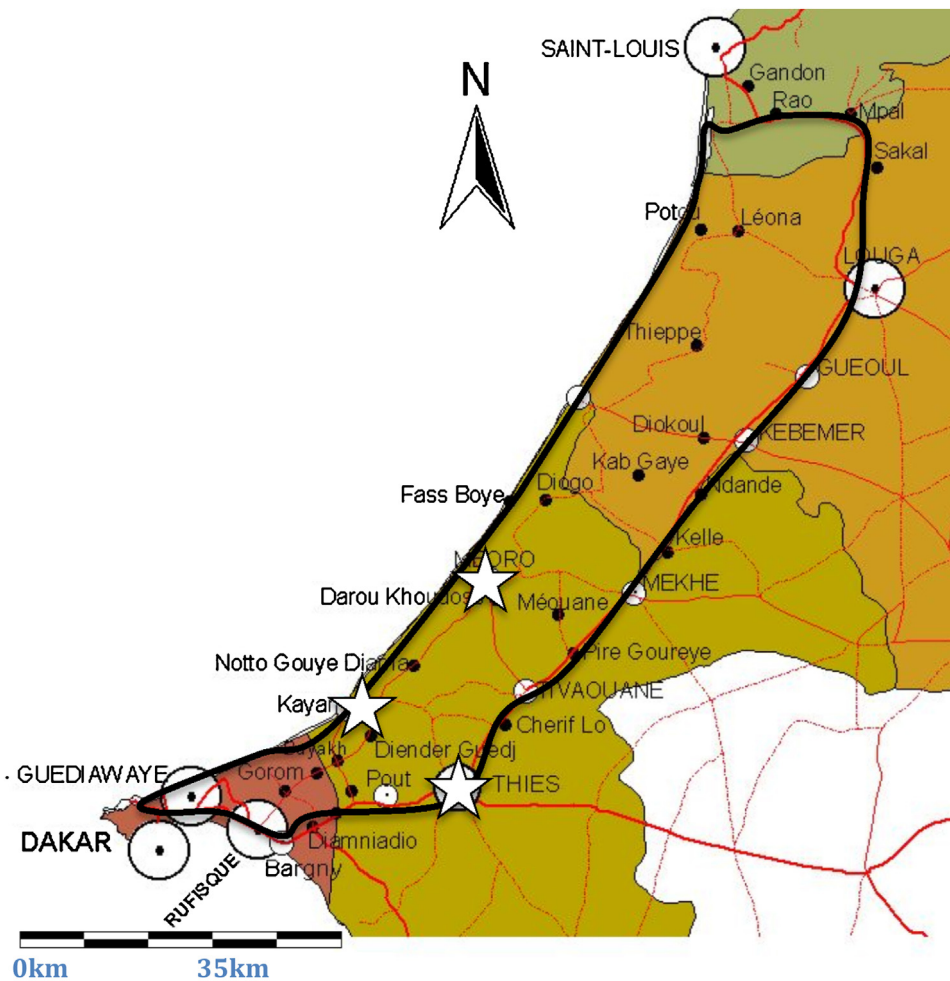


Fig. 1. Regional Map of the Niayes (outlined in black). Stars indicate where data collection occurred and circles represent cities with more than 50,000 inhabitants. Reprinted and modified from: Scott, Faruqui, & Raschid-Sally, 2004.

of social, economic, and environmental constraints to production, including an inability to locate markets, a lack of agricultural credit institutions and high quality inputs, proper storage facilities, and contaminated water from agricultural inputs. Cooperatives have subsequently emerged as the primary strategy for smallholders in the Niayes to organize and collectively confront these ongoing constraints. Our research activities were focused on two producer cooperatives in the region, one identified as ‘well-functioning’ and the other ‘poorly-functioning’. These cooperatives were identified through a joint-ranking activity using key informants drawn from the government, development, and civil society sectors working with smallholders in the Niayes. Using a list of approximately 20 producer cooperatives, the key informants collaboratively ranked each cooperative on a scale from ‘successful’ to ‘needs improvement’ (following the process described by Mulhall & Taylor, 1998), subsequently resulting in the selection of a ‘well-functioning’ (CO-OP A) and ‘poorly-functioning’ (CO-OP B) cooperative.

3.2. Data collection

Primary data were collected using a household survey and semi-structured interviews with key informants involved in cooperatives, development organizations, and government in Senegal. The household-level survey was designed based on the work of Grosh and Glewwe (2000) and Angelson (2011). The survey was conducted between February and April 2015, with 202 producers in total (136 members in CO-OP A and 66 members in CO-OP B) located

in approximately 17 villages spread between three different communes: Diender, Thies, and Mboro. The survey instrument sought information on: i) basic demographic characteristics; ii) agricultural activities including participation in donor-funded projects, leading agricultural constraints, and reason for cooperative adherence; iii) social capital, including questions measuring levels of trust in village members, leaders, and government officials, propensity to collaborate, information and communication flows, and groups and social ties. We used three questions to assess self-reported innovation and social networks: 1) In the last 5 years have you developed or adopted a new crop, a new way of doing things, new planting method, new pest management technique, soil or water management or some technological learning in agriculture; 2) Who are the persons who typically share these “new” ideas with you?; 3) Who are the persons with who you usually share these “new” ideas, new ways of doing things, new crops (specifically related to your farm or farming) that you have adopted? (Table 2). An initial version of the questionnaire was pre-tested with cooperative members and back translated in collaboration with enumerators to improve clarity and reduce potential survey biases.

A sampling frame was constructed for both CO-OP A and CO-OP B using a combination of a stratified random and snowball sampling techniques. The primary reason for this approach was that the cooperatives did not possess a comprehensive list of their members, which prevented random sampling. In order to maximize the representativeness of our sample, we selected households

Table 1
Individual level network measures of social capital.

	Measure	Description	Social capital advantage
Tie Strength	Tie strength (Festinger, Schachter, & Back, 1963)	The intensity of relationship between two actors	Tie strength is associated with bonding social capital, generating trust, facilitating information, and providing social and emotional support (Bodin, Crona, & Ernston, 2006; Prell, Hubacek, & Reed, 2009).
Centrality	Degree centrality (Freeman, 1979)	The number of immediate contacts an actor has in a network, measuring local centrality.	Highly central actors possess various options for receiving and sharing information and resources. It is also associated with influence and the ability of an actors to hold power over the transmission of information (Freeman 1979; Borgatti, Jones, & Everett, 1998)
	Eigenvector centrality (Bonacich, 2007)	The local network of actors immediately adjacent to your focal actor.	Captures how well connected the actors are and how well connected are the actors they have ties to are, illustrating their reach and influence (Borgatti et al., 1998). Key for information access (Banerjee & Duflo, 2011).
Brokerage	Betweenness centrality (Freeman, 1979)	Measure how often an actor falls on the shortest path length between two other actors.	Actors with high betweenness centrality are able to not only access diverse resources and information, but control their flow between actors (Borgatti et al., 1998; Prell, 2011).
	Bridging ties (Borgatti et al., 1998)	Ties that bridge different social groups at similar scales (ie. Ties between villages).	Allow actors to access diverse information and resources, increasing their opportunities for action (Burt 2012), innovative capacity, and resilience (Bodin & Crona 2009; Prell et al., 2009).

from different cooperative sub-villages proportional to the cooperative population and households representing both leadership and general member roles in the cooperative. Before proceeding with the surveys, the research team contacted and met with each cooperative’s President in order to introduce the team, the research objectives, and build legitimacy with the chosen communities. Stratified random sampling involved identifying potential sub-groups (villages in CO-OP A and *groupements* in CO-OP B) and then randomly sampling a representative number of sub-groups (11 villages in CO-OP A and 6 *groupements* in CO-OP B) using a random-number generator. Once the sub-groups were chosen, the study team contacted the local representative of each village (by telephone) to organize a meeting and subsequent sampling list. The contacted representative then provided us with the details of between 10 and 14 cooperative members. Following a secondary check to ensure that the selected participants fulfilled our key criteria, each member was surveyed in the local language (Wolof) by one of two enumerators.

In addition to the survey, thirty-five key informant interviews were conducted using semi-structured questionnaires (Johnson, 2001) to help contextualize and triangulate quantitative data findings (Freeman, 2006). Respondents included a wide range of stakeholders including policy-makers, leaders of producer cooperatives, producers, civil-society leaders, and development practitioners. They were selected following a purposive sampling strategy (Creswell, 2013) that combined snowball sampling and convenience sampling techniques. Interviews ranged from 20 min to 1 h and 25 min depending on the participant’s preference and their level of interest. Each participant understood the purpose of the research and consented to be audio recorded (DiCicco-Bloom & Crabtree, 2006).

3.3. Data analysis

Survey data (from cooperative members) were analyzed using Social Network Analysis (SNA) to provide a more “holistic insight into the structure of a system and the interdependence between entities” (Spielman et al., 2011 p. 403). SNA draws on graph theory and mathematical modeling to investigate the social structures between identified stakeholders (Kadushin, 2012; Scott, 2012) and

Table 2
Overview of name-generating questions used in the household-level surveys.

Relation	Questions:
Flow (Innovation dissemination)	Who are the persons (relatives, friends or neighbours) who typically share these “new” ideas with you? Who are the persons with who you usually share these “new” ideas, new ways of doing things, new crops (specifically related to your farm or farming) that you have adopted?

has been applied across a wide variety of disciplines, including sociology, political science, and more recently, natural resource management and community-based management (see, for example, Douthwaite et al., 2006; García-Amado, Pérez, Iniesta-Arandia, Dahringer, & Reyes; Saint Ville, Hickey, Locher, & Phillip, 2016). Sabatini (2009) noted that the most appropriate network measures of social capital depend greatly on the context and nature of the ties that make up the network. Table 1 summarizes the measures we included in our study, including a description of each measure and the potential social capital advantage based on the literature. We sought to address the social networks operating within our selected producer cooperatives by focusing on self-reported innovation sharing and provision. In network terms, this meant that we focused on the ego-centric level of analysis by using the perspective of a focal node based on relations of “innovation shared” and “innovation provided”. As our network analysis was conducted within a formal structure, we defined the network boundary in three ways: spatially (within the cooperative’s intervention zone), temporally (at the time of study), and organizationally (a member of the cooperative). Network data were analyzed using the software UNICET and NetDraw.

Qualitative interview data were translated and transcribed in full to enable content analysis (Hsieh & Shannon, 2005) and constant comparison to identify and code emergent themes and categories in the data (Auerbach & Silverstein, 2003). Data were coded manually following an iterative process that involved the use of research memos and quotes from participants.

Table 3
Survey respondent attributes (n=202).

	COOP A	COOP B
n	136	66
Age	0 (0%)	9 (14.5%)
18-24	14 (10.3%)	13 (21.0%)
25-34	18 (13.2%)	11 (17.7%)
35-44	26 (19.1%)	15 (24.2%)
45-54	78 (57.3%)	14 (22.6%)
Over 54		
Education	28 (20.9%)	8 (12.9%)
No official education	13 (9.7%)	17 (27.4%)
Primary School	12 (8.9%)	7 (11.3%)
Secondary School	59 (44%)	20 (32.2%)
Religious	6 (4.5%)	4 (6.4%)
Superior Education	16 (11.9%)	6 (9.7%)
Other (includes basic literacy/primary school plus religious schooling)		
Experience	0 (0%)	1 (1.6%)
Less than 1 year	2 (1.5%)	1 (1.6%)
1-2.5 years	2 (1.5%)	5 (8.1%)
3-6 years	2 (1.5%)	0 (0%)
7-10 years	129 (95.5%)	55 (88.8%)
Over 10 years		
Years living in the community	0 (0%)	1 (1.6%)
Less than 1 year	4 (2.9%)	3 (4.9%)
1-2.5 years	3 (2.2%)	4 (6.5%)
3-6 years	2 (1.5%)	1 (1.6%)
7-10 years	126 (93.3%)	52 (85.2%)
Over 10 years		
Land size	45 (35.6%)	2 (3.4%)
Less than 1 ha	62 (46.3%)	35 (60.3%)
1-3 ha	20 (14.9%)	16 (27.6%)
4-6 ha	3 (2.2%)	3 (5.2%)
7-10 ha	4 (3.0%)	2 (3.4%)
Over 10 ha		

3.4. Assumptions and limitations

Five critical assumptions were made in order to assess innovation networks using the SNA approach: 1) positive and negative social capital is embedded in a cooperative member's social relationships; 2) relationships that affect cooperative performance can be studied and local actors are willing to participate in a safe and non-threatening research environment; 3) relational ties between actors adequately capture the channels that innovation (whether material or information) is transferred through; 4) that cooperative members are likely to know one another thereby allowing the use of a snowball sampling strategy; and 5) network structures provide opportunities for, or constrain, individual action, and adequately capture the patterns of relationships. Furthermore, we recognize the potential selection bias resulting from using local leaders to help us identify members and key informants; however, their addition provided important local legitimacy with the potential participants (Scott, 2012). We therefore included a secondary check, ensuring that the selected participants fulfilled certain key criteria such as membership in our selected cooperatives and deriving their primary livelihood from agricultural production (Johnson, 2001). Non-response bias was minimized in two ways: 1) prior notice to survey participation; and 2) revisiting the participants at a suitable time (as recommended by Dillman, 1991). Less than 10% of invited survey participants did not complete the survey.

4. Results and discussion

4.1. Respondent profile

Survey respondent profiles are presented in Table 3. Overall, respondents from both cooperatives reported similar levels of time living in the community (over 85% spent 10 years or more), land

size (65% possessed under three hectares of land), cultivating experience (over 88% had 10 years or more of experience), and low levels of education (less than 20% had undertaken secondary school education). According to Dahkil and Clercq (2004), low levels of education can constrain the ability of smallholders to adopt technological innovation and access specialized training – both of which affect innovation dissemination (Klerkx, Van Mierlo, & Leeuwis, 2012; Lowitt et al., 2015).

4.2. Innovation networks

Social networks pertaining to innovation provision (Q5) and innovation sharing (Q6) in each cooperative are presented in Fig. 2a and b. Our results show that the 'poorly-functioning' CO-OP B's innovation provision and sharing networks (Fig. 2b) were dispersed, highly centralized, and comprised of several cohesive sub-groups. Outside of three important focal nodes that play bridging roles between the sub-groups, there is an apparent lack of connection, indicating a low amount of group cohesion and a high level of modularity. This type of social network structure speaks to what Granovetter (1973) denoted as weak ties, where sub-groups that possess high bonding social capital (i.e. groups with a homogeneity of belief, location, and knowledge), might hinder effective information flow across the co-operative group (Burt 2004, 2009; Warriner & Moul, 1992). The apparent lack of connection between sub-groups in CO-OP B potentially inhibited the cooperative's group structure from playing essential innovation system roles such as innovation intermediation, bridging members to technical and financial resources, and sharing knowledge. This is highlighted in the observation of one interview respondent: "The information doesn't reach between villages because of the problems posed by poor communication channels when there is no access to electricity or internet to help spread information." As a result, he continues, "... This forces the cooperative leaders to share information the 'old fashioned' way, face-to-face, which is not always financially viable for them."

In contrast, the 'well-functioning' CO-OP A's innovation provision and sharing networks (Fig. 2a) exhibited a core/periphery network, outlined by Bodin and Crona (2009) as containing a set of densely connected nodes (the core) that are equally well connected to their periphery group (members) as their other core nodes. The implication of this structure is that peripheral nodes often have strong connections to their core and adjacent nodes, but rarely possess a link to other periphery groups, which can lead to the potential for 'structural holes' (Burt, 2000). Structural holes occur when two actors or groups (peripheral nodes) have no direct connection between them, yet there is a third actor or group (core) that possesses ties to both of them, creating a potential advantage for that third-party who can broker the flow of knowledge and control the interaction between subgroups, thereby influencing the spread of innovation. Despite the possible negative implications arising from the presence of structural holes (for an in-depth discussion of this see Burt, 2009), a core-periphery model is not out of place in a cooperative's hierarchical structure, contributing to its ability to encourage innovation. An increase in horizontal linkages between periphery members would likely encourage farmer-to-farmer connections, potentially facilitating social learning and knowledge sharing (Pretty & Smith, 2004).

Building on these initial findings, we now consider how innovation spreads in each network and what factors influenced this spread drawing on our survey and key informant interview data in order to paint a richer and deeper understanding of both outsider and insider view of the networks (Edwards, 2010).

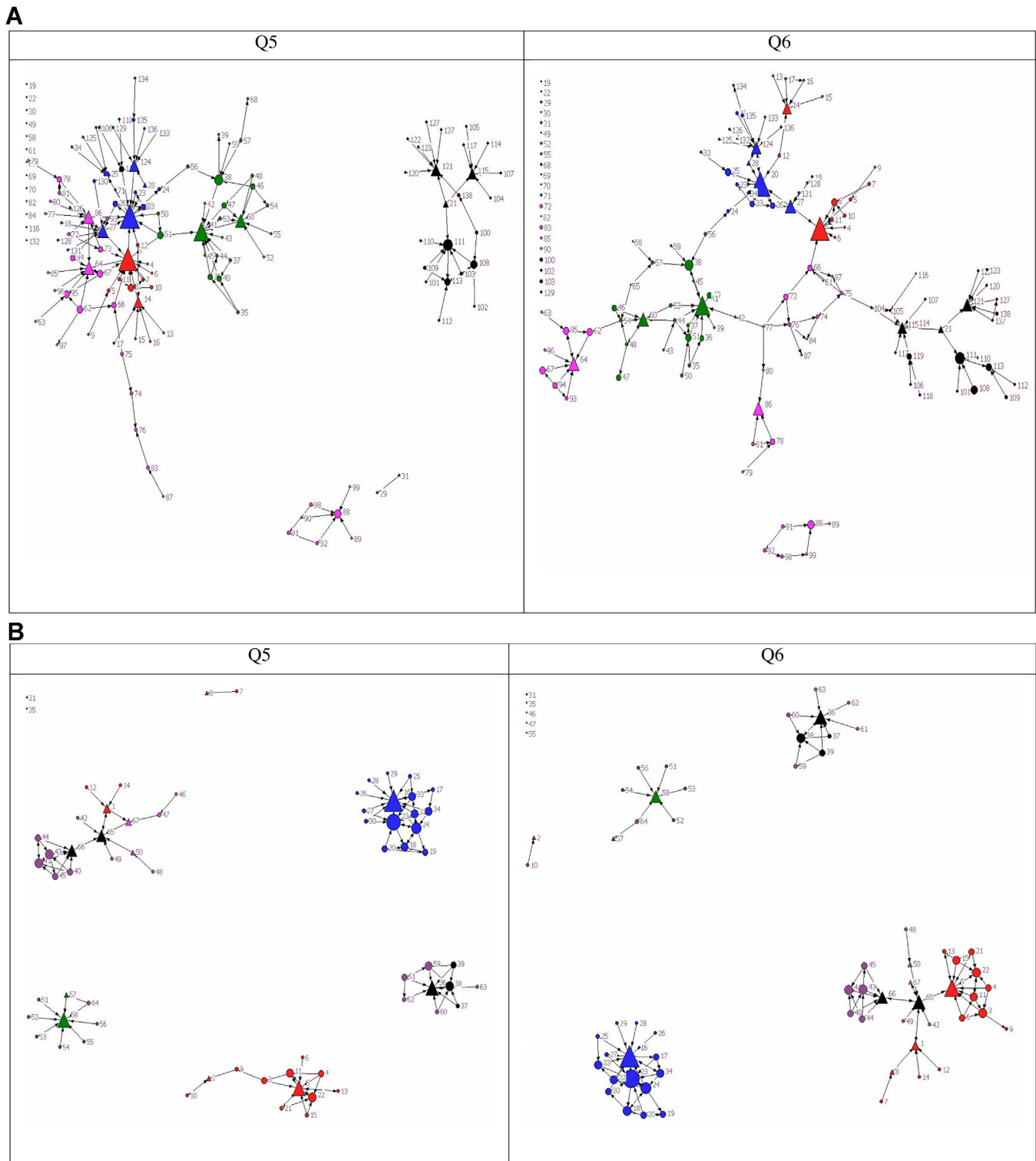


Fig. 2. a Innovation sharing and provision networks, concerning whom you receive knowledge/innovation from (Q5) and who you share this information with (Q6), for COOP B (n = 66) Colours represent sub-group attribution (village-level). Numbers represent individual members. Triangles equal actors in positions of power and circles are general members.

b Innovation sharing and provision networks, concerning whom you receive knowledge/innovation from (Q5) and who you share this information with (Q6), for COOP A (n = 136). Colours represent sub-group attribution (Union-level). Numbers represent individual members. Triangles represent actors in positions of power and circles are general members.

4.2.1. How does innovation spread?

Our results indicate that for both cooperative A and B, innovation spreads in a predominantly vertical manner, where highly connected actors, generally in leadership positions, act as intermediaries between cooperative members and external agents (i.e.

government officials, development workers, etc.). This finding is supported by the work of Krishna (2002) who found that appropriate agents are needed to activate the communities' endowments of social capital to produce a flow of benefits.

The vertical nature of CO-OP A's core-periphery structure was evident as villages elected representatives to the cooperative, who then designated certain individuals at the cooperative level to act as intermediaries for the entire cooperative. We can see this in the core-periphery model where core agents (leaders) hold key roles in the exchange of information between other members. As a result, CO-OP A offered considerably more opportunity for information and knowledge exchange than the more dispersed, heavily divided social network structure of CO-OP B. In CO-OP B, important bridging and linking actors that could potentially connect sub-groups were not present, limiting their ability to transmit innovations and generate solidarity between members. This reinforces the importance of designing cooperative structures that can build bridging connections between geographically separate sub-groups as well as the importance of developing linking connections to facilitate innovation between cooperative members and external agents (Hussein, 2001)

In both of our cases, a few key individuals can be seen as brokering information transmission and thus innovation dissemination within the cooperatives. Drawing from organizational research literature, this level of centralization can have a potentially negative impact on innovation outcomes, as it tends to concentrate decision-making power in one location (Damanpour, 1991). Often, more dispersed power is necessary to promote system-wide innovation (Thompson, 1965). Furthermore, the governance structure of cooperatives as democratic and member-driven generally requires that ownership rights (or the rights that assign benefits) not be assigned to one person; rather they should lie in the hands of the members (Bijman & Hendrikse, 2003). This means that more horizontal ties between the peripheries could potentially increase collective actions in support of innovation. Bourgeois and Friedkin (2001) determined that collective action between members is substantially more likely between actors that are in contact compared to those that are not in contact. Similarly, Pretty and Smith (2004) argued that agricultural innovation flows and opportunities for social learning could be improved by developing stronger farmer-to-farmer connections in different communities. This suggests an opportunity for cooperatives-related policies and communication initiatives to better connect peripheral members to ensure that knowledge and innovation dissemination flows both horizontally and vertically through careful design and the strategic use of participatory approaches.

4.2.2. What influences innovation spread?

Our sample of smallholders reported being highly dependent on a relatively small number of key actors (primarily cooperative leaders) for their agricultural inputs, possible innovations, general information, and market information. This finding further attests to the important role that individuals, and specifically leaders and well-connected individuals, play in the transmission and spread of innovation in agricultural systems (Klerkx & Leeuwis, 2009; Klerkx et al., 2009; Saint Ville et al., 2016). One potential strategy here may be to develop greater linkages between cooperatives and broader 'innovation platforms' – defined as a "multi-actor configuration deliberately set up to facilitate and undertake various activities around identified agricultural innovation challenges and opportunities" (Kilelu, Klerkx, & Leeuwis, 2013, p. 66).

Qualitative data confirmed the central importance of social relations (i.e. whether or not they were included in the immediate friendship circle of members in leadership roles) in accessing innovations, including new agricultural technologies and participating in externally funded development projects. While our survey data indicated high levels of support and trust for village and cooperative leaders (approximately 95% of respondents trusted them), the interview data painted a different picture, with some mem-

bers citing these leaders as being the root cause of problems in the cooperative's function.

If we examine the network structure for both CO-OP A and B in terms of components, we can see that the majority of smallholders were linked only to one another through key actors, illustrating the existence of structural holes in the network (see Fig. 2a and b). This suggests that information and resources from peripheral actors (e.g. average cooperative members) often needed to pass through key actors to reach other smallholders and external actors. Management's role in the operation of cooperatives is known to be an important factor affecting the success of cooperatives (Eilers & Hanf, 1999) and this is an area that would benefit from further social network-related research to better identify their roles and reach in smallholder agricultural innovation systems, particularly in developing area contexts. In our case studies, those who occupied leadership positions often possessed higher levels of education (i.e. were able to speak French), and had deep roots in their community, possessing more ties that enabled the linkage of otherwise unconnected actors to each other, as well as the bridging of sub-groups. Through the application of an attribute analysis (i.e. looking at network structure with circles representing leaders), we subsequently found that members with leadership roles were centrally located and possessed high 'betweenness' and density scores in each cooperative. Our qualitative interview data from both cooperatives supported this finding:

"The dirigeants (managers) take what pleases them and don't share with the little producers" – COOP A member

". . . the dirigeants (managers) have all of the information and they choose what to share and with who. . ." – COOP B member.

While the centrality of leaders is not surprising, careful attention should be paid to their potential role in fostering innovation within cooperatives (Degenne & Forsé, 1999; Sandström & Carlsson, 2008). Importantly, not all leaders will recognize their central role in the innovation system without appropriate institutional support structures. For example, Szreter and Woolcock (2004) differentiate between forms of responsive and unresponsive linking capital, where the latter tends to reinforce nepotism and power asymmetries. In such cases, Bourgeon and Chambers (1999) suggest that the organizational and governance structures of cooperatives must actively address inequality, ensuring that all members possess similar bargaining power.

Despite our sample of cooperative members reporting participation in annual general assemblies and occasional collective seed buying activities, they did not generally feel that they played an important role in the cooperatives' decision-making processes. This finding is supported by Iliopoulos (2003), who noted that cooperative members often have little or no sense of ownership even though they are, by definition, the owners of the cooperative. Our interview data suggested that cooperative leaders could take advantage of this unequal power to a certain extent by filtering information for personal benefits as captured by this quote:

"There are certain unions where the leader manages everything. Everyone and everything has to pass by him. If [the union] received support in the form of equipment or finances, in place of sharing this information or that money or that equipment with everyone, he personally gives it out." – Development official

Fostering broad-based participation and more democratic governance structures has the potential to ensure greater accountability of local leaders (Rahman, Sarker, Hickey, Haque, & Das, 2014; Rastogi, Thapliyal, & Hickey, 2014) and empowerment of regular members, however this is an area that requires further empirical research.

4.3. Innovation challenges facing members

Organizing smallholders into collectives (including cooperatives) is generally understood to improve market access (Devaux et al., 2009), reduce the transaction costs of accessing inputs and outputs (Markelova, Meinzen-Dick, Hellin, & Dohrn, 2009), and increase access to knowledge networks (Herbel, Rocchigiani, & Ferrier, 2015; Ganpat et al., 2014). While this is often the case, our results indicate that this is not necessarily the outcome, supporting the view that the success of collective action in support of innovation depends greatly on factors such as group organization, farmer and product characteristics, as well as the institutional arrangements surrounding their creation (Markelova et al., 2009). Drawing on both our semi-structured interview and survey data, we identified three factors including a lack of information, lack of financial capital, and a lack of access to markets that constrain agricultural innovation in both of the agricultural cooperatives we studied.

4.3.1. Lack of information

Despite the formal structure of a cooperative, our survey data indicated that smallholder's innovation networks were divided significantly along village and union sub-group lines. This is consistent with Tajfel and Turner's (1979) theory of Social Identity, as In-Group and Out-Groups were identified between cooperative leaders and members. The majority of respondents who identified access to information and technical assistance as key impediments to their adoption of new technologies, crops, or agricultural practices were women. For example, in response to a question asking whether they had adopted a new technology or innovation during the last five years (Q49), 30% of responding farmers answered that they had not, all of which were women. For those who had adopted a new technology or innovation during the last five years, friends and family (55%), the cooperative (18%) and the telephone (10%) were reported as being the most important sources of assistance. This result suggests that smallholders are likely to draw on their immediate social network to access knowledge (Lyon, 2000) and transfer agricultural innovation (Conley & Udry, 2001), resulting in the potential for them to become trapped in a cycle of low innovation adoption without external intervention. For the cooperative, developing communication strategies that put more peripheral members (smallholders) in contact with other members and outside technical resources has the potential to yield more decentralized knowledge networks (Olaitan, 2006). One potential strategy suggested by a key-informant working in a development organization was greater use of community radio as a decentralized strategy to diffuse knowledge, foster innovation and disseminate market information: "With community radio, we can distribute a lot of information, even information not in French but in national languages in order to ensure everyone has access to the maximum amount of information." This is an area that requires further research in the context of upscaling and outscaling in agricultural innovation systems (see Hermans, Stuijver, Beers, & Kok, 2013).

4.3.2. Lack of financial capital

A lack of access to financial support, whether in the form of credit or philanthropic donations, was one of the primary constraints to innovation adoption reported by our sample of producer cooperative members. Importantly, of the 26% of farmers who identified access to financial capital as being a key impediment to their innovation adoption, 64% were female. Some interview data revealed that collective initiatives arranged through the cooperative enabled certain groups of producers to better access finance for agricultural tools and equipment. However, the producer's ability to access this credit and external support (i.e. from the local development bank, Programme d'Aménagement et de Développement Economique des Niayes) appeared to depend heavily on the social connections

they held. Findings from interviews and informal interactions identified a growing amount of inequality between cooperative leaders, their friends (core actors) and other members of the cooperative. CO-OP B illustrated this inequality particularly clearly as members in leadership positions complained that only 8% of members actively participated in the cooperative and its services, including receiving its benefits. Part of the reason for this was a lack of information (as explained above); however, a more confronting reason could be the perceived disconnect between members (as participating actors in the cooperative) and the leaders/central management of the cooperative. One key-informant outlined the importance of members actively participating in the functioning of the cooperative, and made reference to the potential ramifications of non-participation:

"The members need to personally participate in the functioning of their organisation to ensure that it survives. Unfortunately, in most instances this is not the case as the members have the tendency to think that it's the organisation (management) that will deal with all the problems. For me, the [problem is] members who participate in an organisation without understanding their role, nor the operation of their organisation."

Disparities in the level of involvement of members were generally associated with disparities in their ability to access financial resources according to our key informants. This suggests a potential role for micro-finance institutions that can enable smallholders to access financial capital in an equitable manner (Ellis, 2000; Lowitt et al., 2015).

4.3.3. Markets

The inability to access both local and export markets also emerged as constraints to agricultural innovation within both of our case study cooperatives. This highlights the importance of institutional structures that can both support innovation systems while also better linking farmers to markets for their produce. For example, one respondent stressed the need for an awareness campaign advocating the benefits associated with eating locally-produced organic foods in order to help build a market for his organic produce – an innovation common to both cooperatives we studied. Several farmers described their challenge to compete with imported products from European markets, particularly onions and potatoes. As onions occupy an essential place in many traditional Senegalese dishes, smallholder's calls for the government to change importation laws have been extensive. In one of our interviews, a government official noted ". . . it is difficult for agricultural producers in the region to earn their living if the market is saturated with foreign imports." The government has begun to answer these calls with increasingly strict regulations to control onion and potato imports in certain seasons, speaking to the important role that formal institutions can play in the development of fragile local production and innovation systems amongst rural smallholders (Hounkonnou et al., 2012; Shiferaw et al., 2009).

5. Conclusion

Our comparative case study indicated that knowledge and innovation was spread, in the formal cooperative structures, through predominantly vertical linkages where highly connected actors, generally leaders, acted as intermediaries between high-level partners (governments and markets) and the cooperative members. These key actors were reported as receiving significant power from their role, potentially resulting in a wide variation of knowledge and adoption of innovative practices across cooperative members, due to their ability to control the flow of knowledge. Our results also suggested that individual-level social networks not only dif-

ferred greatly between members, but also affected their potential to access and share knowledge concerning innovation. This finding challenges the notion that cooperatives are inherently positive vehicles for innovation dissemination (Clark, 2002; Gouet & Van Paassen, 2012; Yang, Klerkx, & Leeuwis, 2014), and instead suggests the need to better recognize that their function depends heavily on the existing social capital of cooperative members. Future research into the role of individual social capital (including social networks) in the function and performance of agricultural cooperatives could help to better understand the internal politics of cooperatives and how different forms of power are obtained and used to enhance the opportunity of different members.

Our findings support the need for members to have both structured and unstructured opportunities to connect with internal (other members) and external agents, building the social capital necessary to access wider networks of information (Sabatini, 2009). This type of thinking may provide an opportunity for cooperatives to better intersect with agricultural innovation platforms seeking to facilitate forums for interactions that can build trust, collaboration, and networks between multiple stakeholders in the food system (Foran et al., 2014). Through these avenues, new opportunities may be identified to re-center cooperative-related research on member dynamics and interactions and how the values of “autonomy, voluntarism, and democracy” in cooperation can be best fostered. Important considerations here include the potential roles that agricultural cooperatives might play in empowering disadvantaged groups in rural landscapes, such as ethnic minorities, youth and women; and confronting the basis for the often-negative local perceptions surrounding cooperatives and their colonial legacies in order to collectively identify new arrangements and directions.

Following this theme, one research participant likened the cooperative model to an instrument such as a car, saying that it is not the instrument in itself that is good or bad, but rather the utilization and exploitation by people that influences its success or not. This observation speaks to the importance of regulating cooperative identity and ensuring that all members feel empowered, which Alvesson and Willmott (1992) argued is a “significant, neglected and increasingly important modality of organizational control” (p. 5). In this context, further exploring how social inequalities and gender differences between members affect cooperative design, direction, management, and performance in different settings would be valuable. Encouraging cohesiveness through group activities of training, informal networking events and education that increase the number of potential information and knowledge sharing opportunities (Scott, 2012) and opportunities for farmer-to-farmer connections in different communities (Pretty & Smith, 2004), may facilitate the development of a more discernable ‘collective’ identity and improve cooperative activities, such as joint marketing, financing, and political lobbying (Woolcock & Narayan, 2000). Ultimately, there is a need to better integrate economic and social factors in the analysis and evaluation of agricultural cooperatives in order to more meaningfully assess the distribution of benefits and the costs of membership, particularly in rural smallholder landscapes such as those found in Senegal.

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