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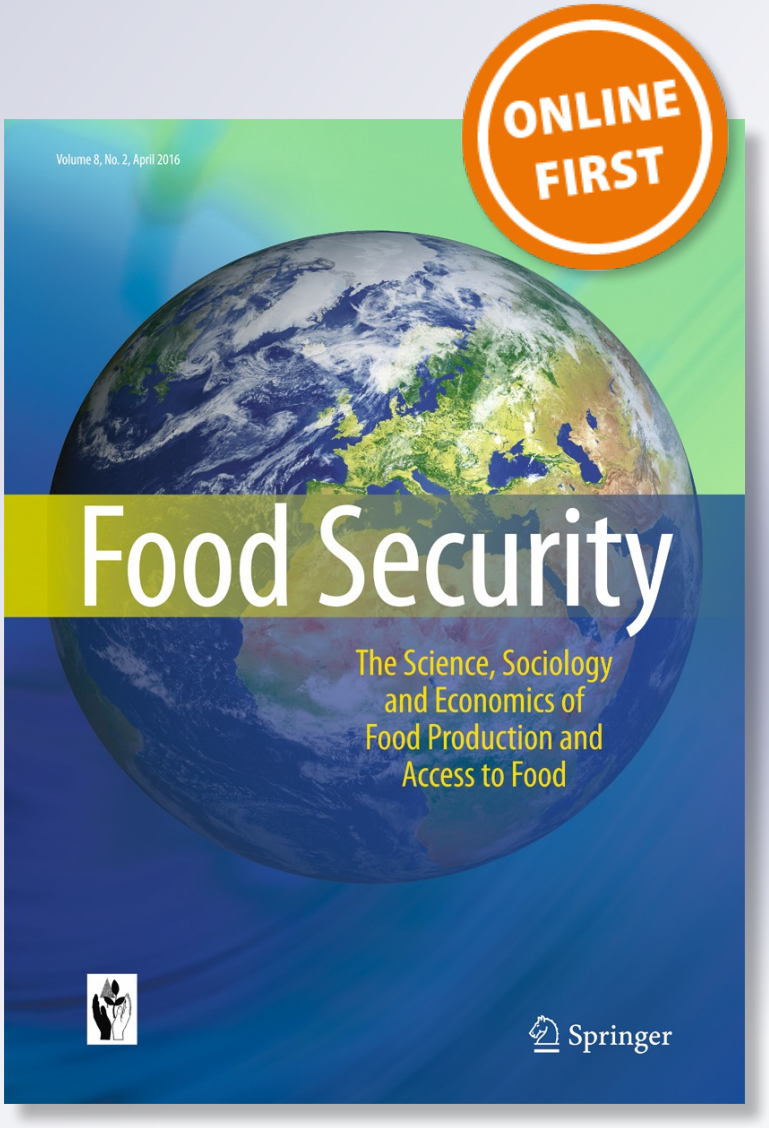

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ORIGINAL PAPER

Exploring the role of social capital in influencing knowledge flows and innovation in smallholder farming communities in the Caribbean

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Abstract This paper presents the results of an exploratory study into how different forms of social capital embedded within community-based social networks may affect innovation in smallholder farming systems to better support food security in the Caribbean. Focusing on two rural communities in the small island developing nation of Saint Lucia, our results indicate the strong presence of interpersonal agricultural knowledge networks operating to: 1) facilitate farmer-to-farmer knowledge exchange; 2) increase farmer access to information; and 3) connect farmers to sources of support. In both communities, 'peer farmers' were reported as being the primary source of new agricultural knowledge for farmers, with government 'extension officers' the secondary source. Comparative social network analysis reveals how different forms of social capital within the two agricultural knowledge networks can affect self-reported farmer innovation in different contexts. Based on these findings we identify a number of opportunities for policy initiatives to better support, coordinate and enhance innovation opportunities among smallholder farmers in the Caribbean with a view to building their adaptive capacity in the face of environmental change. The findings provide important evidence and insights relevant to the governance of domestic agricultural systems and regional food security programming in the Caribbean.

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Introduction

Despite extensive research and technological investments in international agriculture, the ways in which institutional arrangements support or undermine sustainable farming systems remain generally poorly understood (von Braun 2009; Godfray et al. 2010; Grote 2014). Importantly, agricultural system innovation in high risk or fragile natural environments requires careful institutional management of informal and formal knowledge systems (Brooks and Loevinsohn 2011), particularly in the context of the smallholder farmers operating in developing areas (Foley et al. 2011; Anthony and Ferroni 2012). Many studies have identified the potential for smallholder agro-ecological approaches to promote social and ecological sustainability in different developing area settings (Pinstrup-Andersen and Hazell 1985; Pinstrup-Andersen et al. 1999; Conway 1987; Pinstrup-Andersen and Herforth 2008); however, their potential to innovate is often undermined by limited access to resources, low levels of technology adoption, difficulties in coordination, asymmetries in information flow, and high levels of exposure to external and internal shocks (Dorward and Kydd 2004; Kydd and Dorward 2004; Birner and Resnick 2010).

The smallholder farming systems found in the Caribbean's Small Island Developing States (SIDS) confront additional difficulties to innovation (Briguglio 1995; Lowitt et al. 2015b; Saint Ville et al. 2015) including high levels of exposure to market shocks, competition from relatively cheaper imports, resource conflicts from growing tourism development, and losses from extreme weather events and other

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natural disasters (Timms 2006, 2008; McGregor et al. 2009; López-Marrero and Wisner 2012).

Innovation adoption studies began with the Green Revolution's quest to better understand the transfer to farmers of divisible agricultural technologies developed at research institutes and universities (Zilberman et al. 2012). At that time, agricultural innovation theory and practice generally equated food security with food availability (Maxwell and Wiebe 1999; Scoones et al. 2009). More recent developments have accepted food security as being multidimensional, comprising 1) food availability; 2) accessibility; 3) utilization; and 4) stability (Pinstrup-Andersen 2009). Despite this generally agreed upon multidimensionality, the concept of food security has challenged Caribbean governments partly because of the initial bias towards relying on technological solutions to increase food production (Sheeran 2010). Smallholder farmers in the region have often faced market-led (Isaac et al. 2012), or supply-led innovation pressures termed "technology push" (Pant 2013, 341), which have generally not led to enduring solutions. As a result, agricultural innovation efforts to enhance regional food security in the Caribbean are being increasingly recognized as complex and context-specific (Weis 2004; FAO 2012; Isaac et al. 2012). Recent research has identified access to markets, financing and knowledge networks as being critical constraints facing smallholder agricultural innovation in the region (Lowitt et al. 2015b), suggesting the need to better understand how innovation is shaped by relations between social actors (Leeuwis and Aarts 2011). However, very little, if any, empirical research has explored the relationships between actors in contemporary Caribbean agriculture-food systems and how these interactions may work to enhance or limit smallholder farmer innovation in support of context-specific food security challenges.

Social capital, defined as the enduring connections of networks, reciprocity and social norms that exist among a group of social actors (Ostrom 2000), provides a particularly useful conceptual framework when seeking to understand how the interactions between actors in smallholder farming contexts can affect innovation (Lowitt et al. 2015a). In particular, it plays an important role in developing area contexts where strong social ties function to counter poorly developed or weak institutions (Fafchamps 2006; van Rijn et al. 2012; Lowitt et al. 2015a). For example, social capital has been used to assess the barriers and opportunities for rural community collective action (Rastogi et al. 2014; Rahman et al. 2015); to improve understanding of agricultural innovation in smallholder farming systems (van Rijn et al. 2012); to help design more integrative and decentralized policy frameworks (Bodin and Crona 2009; Crona and Hubacek 2010); and to enhance collaborative governance through supportive community institutions (Compton and Beeton 2012). Through such research, social capital has been usefully conceptualized as comprising three dimensions: 1) *bonding* social capital, which includes the horizontal connections found within a group, (also referred to as 'strong ties'); 2) *bridging* social capital, involving the horizontal links that are found connecting or bridging individuals who belong to distinct groups ('weak ties'); and 3) *linking* social capital, described as vertical ties to sources of power and finance developed among social actors involved in shared tasks to improve the common good (Grootaert et al. 2003; Sabatini 2009). While many studies have identified the positive contributions of different forms of social capital to communities, others have identified the 'dark side' of social capital (Rubio 1997; Ballet et al. 2007). For instance, 'network closure' (Granovetter 1973; Burt 2000) can result from bonding social capital leading to increased homogeneity of beliefs, behaviour, and knowledge within the network while reducing exchange with outsiders (see for example, Barnes-Mauthe et al. 2015). Social capital can also favour those who are already well-resourced (Fafchamps 2006; Maertens and Barrett 2013), and may lead to associations that undermine the greater societal good (van Deth 2010).

Recognizing that previous research has identified positive and negative relationships among social capital, information flow, and agricultural innovation in smallholder farming systems (van Rijn et al. 2012; Dessie et al. 2013; Speranza 2013; Wossen et al. 2013; Chen et al. 2014), relatively little is known about the nature and extent of social capital in Caribbean agriculture. This is significant because an improved understanding of social capital dynamics within Caribbean smallholder farming systems has been identified as having the potential to inform sustainable natural resource management policy and practice (Adger 2003; Pelling and High 2005) and contribute to regional food and nutrition security objectives (Lowitt et al. 2015a). In this paper we present the results of a comparative case study designed to explore how the different forms of social capital embedded within community-based social networks may be affecting smallholder farmer innovation in the Caribbean nation of Saint Lucia with a view to informing future research and policy in the region.

Methods

Following a combined grounded theory—case study research design (Glaser and Strauss 1967; Yin 1994), we utilized a mixed methods approach to data collection and analysis, further described below. Our research aimed to better understand the role of social capital in developing agricultural knowledge networks and the ability of farming households to innovate in Caribbean smallholder farming communities. More specifically we sought to explore the association between smallholder farmer social capital and self- reported innovation at the household level (using ego-centric analysis); and community level (using socio-centric analysis). According to Monge and

Contractor (2003), adopting such multi-level analyses increases the comprehensiveness of social network research by identifying the processes occurring at multiple network levels.

Location of the study

Saint Lucia is a volcanic island with rugged topography located within the Caribbean archipelago. The land area is 616 km^2, with approximately 9 % of this considered arable (Cox et al. 2005). Smallholder farms, typically less than two hectares in size, dominate the domestic agriculture-food system which is generally small-scale and rain-fed (GOSL 2007). Seasonality in rainfall, with heavy cyclonic rains in the wet season (from May to November) and a pronounced dry season from December to April (Cox et al. 2005), combined with considerable spatial variation in annual rainfall from mountainous to coastal regions (Isaac and Bourque 2001; Cox et al. 2005) challenge efforts towards consistent food production. The historical dominance of plantation sugar estates on the flatter flood zones has resulted in approximately 87 % of smallholder farms practicing cropping on hillsides with generally fragile soils (Rojas et al. 1988) contributing to high rates of soil erosion and land degradation in many agricultural watersheds (Cox and Madramootoo 1998).

Through a collaborative research initiative between McGill University and the University of the West Indies (2011–2014), two rural farming communities were selected in order to analyze the various factors affecting innovation among smallholder farmers: Black Bay and Marquis (see Fig. 1). These two communities have quite different local histories and institutions in place to support smallholder agriculture (see Table 1); the two communities provide an excellent opportunity to conduct an exploratory and comparative analysis of the role of social capital in agricultural knowledge networks and innovation.

The agricultural history of both Black Bay and Marquis began with sugar plantations but subsequently followed divergent paths. In the case of Black Bay and surroundings, after slaves were freed from plantation labor in 1838, that sugar estate was restructured into one of four central factories (Harmsen et al. 2012). This amalgamation made the Vieux-Fort Factory the major landowner (4000 acres /1619 ha of land) and employer in the area until 1936, when the Vieux Fort Sugar Company shut down causing economic hardship (Harmsen et al. 2012). As part of a World War II agreement, the United Kingdom leased all lands in the area (5000 acres) to the United States military that were subsequently returned to the Government of Saint Lucia with the deactivation of the Naval Base (Harmsen et al. 2012). In 1974, the British Development Division initiated the Black Bay Vegetable Project to promote economic development, comprised of eleven family farms each leasing ten hectares of alluvial plain (IICA 1989). Due to administrative inefficiencies, from 1974 to 1978, production fluctuated and stalled. In 1978, another external injection of technical, financial and administrative resources re-catalyzed agricultural production; however, this increased production was short-lived due to natural disasters and recurring administrative mismanagement (IICA 1989). By 1988 the project's membership had increased (to the current size of 35) and the production acreage doubled (IICA 1989). In 2008, the Black Bay Cooperative became formally incorporated, responsible for managing the state-owned land by allocating farm units (typically 1–2 acres) to its members. While each member independently operates their farm, they engage in voluntary shared product marketing through the cooperative. This involves the cooperative sourcing produce from members in response to orders received (primarily from hotels). Product grading, weighing and packaging take place at the cooperative and is then delivered to the buyer. This is the primary revenue generating activity of the cooperative, with monthly deductions from the payments to members used to support transport, facilities, utilities and staff[1].

Unlike Black Bay, where agricultural lands were owned centrally by the state and ultimately managed through the cooperative, in Marquis farmers enjoyed access to mountainous, forested lands on the periphery of Marquis Estate lands. After the abolition of slavery in 1833, Marquis' 1032 hectare sugar estate remained but experienced labor shortages as ex-slaves opted to hunt, subsist, and squat in nearby mountains rather than enter into voluntary employment on estates. Planters responded by using their legislative authority to institute vagrancy laws, high land sales taxes and licensing fees on transportation to restrict land ownership and create forced labor conditions (Harmsen et al. 2012). Despite these restrictive strategies, where lands were available, a land-owning peasant class developed and by 1890 they produced one-fifth of all sugar grown in St. Lucia (Harmsen et al. 2012). By 1897, an estimated 6000 ex-slaves purchased small farms across the island representing a 347 % increase in land ownership levels from 1845 (see Adrien 1996). Declines in sugar markets in the early 1900s resulted in severe economic hardship but, in 1953, things improved when the British government created a guaranteed market and awarded a British company the contract to buy all Windward Island bananas. This transition from sugar to bananas created many economic opportunities (Grossman 1998) and by 1965, bananas represented 90 % of Saint Lucia's total exports, grown by 12,479 registered growers (O'Loughlin 1968; Welch 1994). Booming export market conditions and labour shortages in Marquis resulted in the private sale of half of the estate (405 ha) in 1980. Initially targeted towards ex-workers at reduced cost in farm sizes ranging from 1 to 10 ha, many failed to meet financing requirements and the majority of the land was sold to people living outside the

[1] The cooperative employs one to two administrative staff, located in a centrally located facility in close proximity to farms and includes two offices, a meeting room, washroom, a storage area and greenhouses.

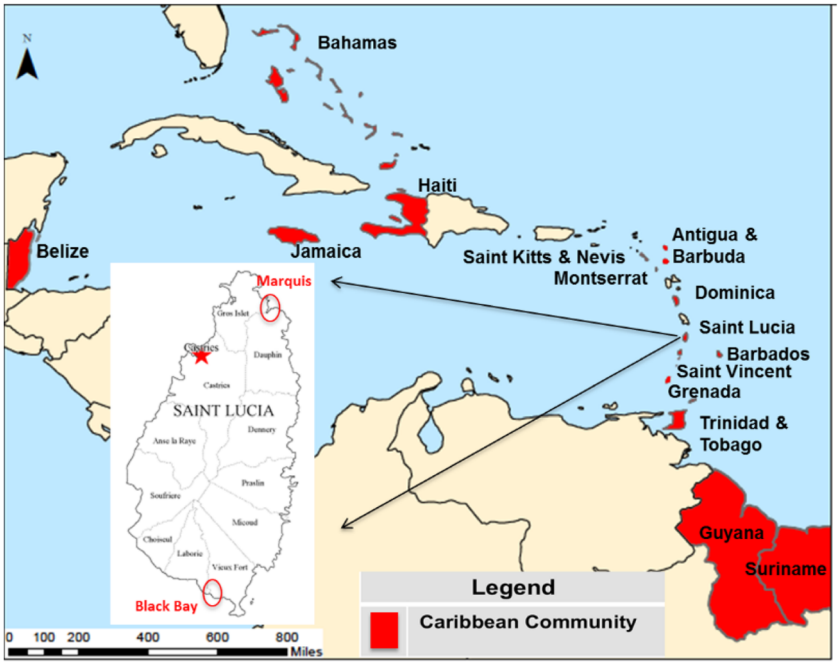


Fig. 1 Map showing Saint Lucia in the Caribbean Archipelago and all fifteen member states of the Caribbean Community (CARICOM). An inset map of Saint Lucia shows the position of the two study sites relative to the capital city, Castries. *Data source (inset map):* http://www.d-maps.com/pays.php?num_pay=157&lang=en

immediate local community (OAS 1986). Post-liberalization, with the loss of the protected market in Europe (1999), farmers in Marquis increasingly abandoned banana production and joined Black Bay farmers in producing fresh fruits and vegetables for local markets.

These private farmers produce, harvest and market their fresh foods for the domestic market independently. On a weekly basis, their short-term crops (including cucumber, peppers, lettuce, green onion, eggplant, okra, tomatoes) are sold to supermarkets, the government-controlled marketing board and directly to consumers at the Castries Farmers Market. Fridays and Saturdays are the major selling days at the market, with crop availability, quality and volumes highly variable.

Table 1 summarizes the major characteristics of each community. Although they have different historical paths and social-ecological conditions, the majority of the smallholder farmers in both communities grow fresh fruits and vegetable for the domestic market. In the case of Black Bay, farmers have a longer history and more experience producing for the domestic market than the farmers in Marquis. Farmers in both communities have easy access to water for irrigation from nearby rivers. Other common characteristics include: 1) low precipitation due to their proximity to the coast; and 2) location on flood plains with fertile, alluvial soils. Key differences can be found in land tenure arrangements and the operation of an agricultural cooperative. In Marquis, farm land is privately owned and held across generations as 'family lands' while in Black Bay all farm land is publicly owned and leased to individual smallholder farmers; the majority of whom access this land through their membership of the Black Bay Cooperative.

Table 1 Summary of community characteristics in Black Bay and Marquis

Community characteristics	Black Bay	Marquis
Active agricultural cooperative involved in domestic production	Yes	No
Rural community	Yes	Yes
Land ownership	Leased (owned by the government)	Owned/family land/leased (private ownership)
Land capability	Alluvial, fertile, flat	Alluvial, fertile, flat and steeply sloping
Banana production history	No	Yes
Livelihood strategies	Fruits and vegetable for the domestic market	Fruits and vegetable for the domestic market
*Number of households in community (estimated involvement of households in agriculture)	138 (50 %)	212 (50 %)

* Based on Enumeration Districts, Saint Lucia 2010 Population and Housing Census: Preliminary Report, 2011

Data collection

We conducted 112 farmer household surveys following a purposive snowball sampling strategy in both communities (40 in Black Bay and 72 in Marquis). In addition, we collected qualitative data through eight farmer focus groups and 55 key informant interviews with community leaders. We also directly observed community farmers during various stages of marketing and production. All field data were collected between June and August 2012 in accordance with McGill's ethical research guidelines.

Smallholder farmer households were the primary unit of analysis and included those directly involved in farm production, such as agricultural labourers, subsistence producers and commercial scale farmers. Locally-oriented agricultural commodities of interest included fruits, roots, and vegetables. Surveys were administered by trained enumerators and conducted on farms and households in English. While surveys were administered in English, questions were translated into 'Kweyol' (a local language used in rural areas) to ensure ease of communication with older farmers as needed. Our surveys followed a snowball sampling strategy to ensure we reached farmers named by respondents in each community. While this sampling approach helped us to identify the type and nature of connections between social actors within what was an unknown network, we acknowledge that it did not allow us to identify disconnected social actors in the network (Hanneman and Riddle 2005) and recognize this as a limitation of our dataset.

Our research design sought to capture a broader picture of local network contexts by using the Socio-Spatial Knowledge Network (SSKN) method (Gregory and Urry 1985), which has been widely applied in the health sector to help identify community spaces for effective knowledge dissemination (Skelly et al. 2002; Gesler et al. 2006). This involved community scoping and discussion with community leaders, including teachers, elected officials, community-based organisations, faith-based organisations, health care workers and civil servants, to better understand the different community issues, gain support for the research, and to understand local needs and concerns (Cravey et al. 2001; Skelly et al. 2002). We then used the survey instrument to examine demographics and attitudes of respondents, the use of activity spaces, prepare a place inventory and identify key nodes/areas for knowledge sharing in each community (Cravey et al. 2001). Activity spaces helped us to identify and select the best locations to meet with potential respondents for surveys and recruit participants for focus groups. The SSKN method ensured that key smallholder farmers in each community were appropriately captured in the network analysis (Forsé and Degenne 1999). We used the community boundaries defined by those people living in the community to ensure the relevance of our network boundaries (Marsden 1990). We applied name-generator questions using a relation-based approach (Borgatti et al. 2009) to elicit the network links directly from respondents. This involved answering questions that required them to name other farmers in the community with whom they had relations of interest: potential sources of farming support, requests for support, friends, sources of new knowledge and recipients of new agricultural knowledge. As a follow-up question, respondents were then asked, "are you related to this person?" to identify kinship associations with these other farmers in their community.

In order to better examine the relationships emerging in our quantitative data, qualitative data were collected using Focus Group Discussions (FGDs) with smallholder farmers in each community (four in Black Bay and four in Marquis) and interviews with community leaders. Qualitative data were important to our study due to the complexity of the issues being explored and the need to contextualize the survey data, including understanding various motives, constraints and mechanisms in more detail (Hancke 2009; Krueger and Casey 2009). Focus group discussions were used to collectively clarify views, attitudes and motivations and delve into shared understanding (Litosseliti 2003). Of the four FGDs conducted in each community, we ensured that one brought together young farmers, and another focused on the unique perspectives of women farmers. The discussion time in each FGD ranged from one to two hours and each comprised between eight and 18 participants. Participants were asked about their agricultural knowledge needs, knowledge networks, sources of knowledge, and were encouraged to draw charts as needed. Each FGD was audio recorded and fully transcribed for coding and analysis.

Data analysis

Our study adopted a broad definition of innovation, as being an "idea, practice, or object" perceived as novel by a social actor or adopter (Rogers 1983, xviii). We operationalized this definition in our study as: adopting a new crop, new way of doing things, new planting method, new pest management, soil or water management technique or some other technological learning in agriculture in the past 5 years. We used two questions to assess self-reported innovation of respondents: 1) Have you ever been involved (at any time) in an agricultural project with the Ministry of Agriculture? (past innovation variable); and 2) 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 (recent innovation variable)? Since the practical aim of the study was to assess how social capital might influence knowledge networks and self-reported innovation in Caribbean smallholder agriculture, the level and nature of the particular innovation was self-reported and not independently verified.

Networks are composed of interactions at multiple levels that may be viewed from the individual, dyad, subgroup and entire network level (Prell 2012). We conducted our social network analysis at two levels, the ego-centric and socio-centric level. At the ego-centric level of analysis, we viewed the network from the perspective of a focal node (ego), based on relations of "knowledge received", and "knowledge shared". We looked at direct connections between the ego and other nodes (alters) (farming households in the community) and the connections among these alters. By isolating the nodes in an ego-network, the software UCINET VI generated a measure of each smallholder farmer households' structural social capital, defined in terms of "size" and "ties". "Size" measured the number of direct connections between the ego and other actors (alters). "Ties" measured the total number of ties among the alters in the ego network (not counting ties involving the ego). We then used these network-derived measures to conduct individual-based (ego) statistical analyses using SPSS VI in order to test the level and significance of association between a respondent's self-reported innovation and their "sizes" and "ties". We selected Goodman and Kruskal's (1954) Gamma to measure this association because of our small sample size, and use of ordinal variables (Gans and Robertson 1981).

For the socio-centric network analysis, we also examined the larger knowledge network to see overall patterns in the network structures of the two farming communities. UCINET VI was used to provide social network measures and graphical analysis was conducted using NetDraw II. Multiple connections (multiplex relations) were mapped to identify the level of overlap among the ties. These multiplex relations were used to develop the community knowledge networks by overlaying three types of ties between respondents and the other farmers in the community (knowledge received, knowledge shared, and kinship/blood ties). Ties were assumed to be bidirectional (B is in A's network if A claims B). The resulting maps of these overlays of relations allowed us to better capture the nature of the bridging (non-overlap with kinship ties) or bonding (overlap with kinship ties) social capital.

Qualitative data were analyzed using content analysis techniques (Altheide 1987; Morgan 1993) looking at key themes in the data around innovation conditions, farmers' attitudes to innovation, trust, farmer-farmer interaction and knowledge exchange (Glaser and Strauss 1967). All qualitative data coding was conducted manually using MaxQDA software.

Results

Table 2 provides a summary of the respondent profile in each community, indicating that most were male and had a marital or common-law partner. Most of the respondents had lived and farmed in either Black Bay (75 %) or Marquis (61 %) for 11 years or more, and more than half of this group had been involved in farming for 21 years or more. The median age range was 45–54 (33 %) in Black Bay and 55–64 (31 %) in Marquis. In Marquis, 18 % of respondents owned their farms, 40 % farmed on family lands[2], and 15 % leased from private landowners. In contrast, 87.5 % of respondents from Black Bay farmed on government land. Over half of respondents reported farming as providing between 75 and 100 % of their income, with similar proportions reporting that their farms were producing under-capacity. Primarily, respondents were dependent on weekly farmers' markets as the primary endpoint for the sale of their crops. Approximately 12 % of all respondents were involved in banana production with the majority of these respondents (17 %) from the Marquis community. More than 50 % of respondents had never been involved in banana production while 38 % of respondents who had been involved in export banana production exited this market primarily in the 1990–1999 period. General trust was low among respondents (85 % in Black Bay and 70 % in Marquis), with relatively higher community trust levels (with distrust at 46 % in Black Bay and 64 % in Marquis). In Marquis, 42 % of respondents claimed membership in the Babonneau Fair Trade Association (a banana exporter group) or other farming groups, while in Black Bay, 65 % of respondents held membership in the Black Bay Cooperative.

Figure 2 shows that in both communities, (75 % in Black Bay and 51 % in Marquis) 'peer farmers' were reported as being the primary source of new agricultural knowledge for farmers, with government "extension officers" the secondary source (39 % in Black Bay and 43 % in Marquis). Innovations identified by respondents included: new crops (kale, zucchini), new planting methods, new pesticides, non-chemical weed management techniques such as plastic mulch, chemicals such as hormones to induce flowering, soil stimulants, use of heavy equipment, new irrigation techniques and seedling development. A key difference in the two communities was the role of 'relatives' and 'friends' in providing new knowledge, reported in Marquis at 36 and 36 % compared to Black Bay at 18 and 20 % respectively.

Generally, Marquis and Black Bay respondents showed similar trends in their self-reported innovation activities. In both communities, qualitative data highlighted that respondents held a positive association with innovation resulting from their participation in past agricultural development projects. Descriptive statistics supported this assertion with 72 % of respondents expressing a willingness to participate in future projects. Two-thirds of respondents in both communities reported that they had adopted an innovation in the past 5 years while 37 % had been involved in past agricultural projects (donor-funded or with the Ministry of Agriculture).

[2] "Family land" is a generational land title and exists in St. Lucia as part of French colonial inheritance laws and results in lands being owned across generations of a family. Typically the land is accessed and used by a multiplicity of heirs, and successors without title by virtue of shared bloodline.

Table 2 Demographic and farm characteristics of survey respondents

Respondent attributes	Black Bay ($n = 40$)	Marquis ($n = 72$)
Demographics		
Male	93 %	72 %
Without a partner	40 %	39 %
Lived in community for more than 11 years	75 %	61 %
Median age range	45–54 (33 %)	55–64 (31 %)
Completed primary school	33 %	35 %
Completed secondary school	43 %	40 %
Completed college	18 %	13 %
Completed university	5 %	10 %
Land ownership		
Land owner	13 %	18 %
'Family land' owner	–	40 %
Leased-Government	87.5 %	–
Leased-private	–	15 %
Co-owner	–	8 %
Share tenant	–	11 %
Production/Marketing/Membership		
Less than ¾ of farmland under cultivation	59 %	56 %
More than ¾ of farmland under cultivation	41 %	44 %
Farming contributes 75–100 % of household income	58 %	50 %
Weekly farmers market –main market	32 %	69 %
Past involvement in banana production	30 %	43 %
Current involvement in banana production	2.5 %	17 %
Membership of cooperative/farmer group	65 %	42 %
Trust		
General trust-most people cannot be trusted	85 %	70 %
Community trust-'strongly agreed' and 'somewhat agreed' that "you have to be alert or someone in this community is likely to take advantage of you"	46 %	64 %

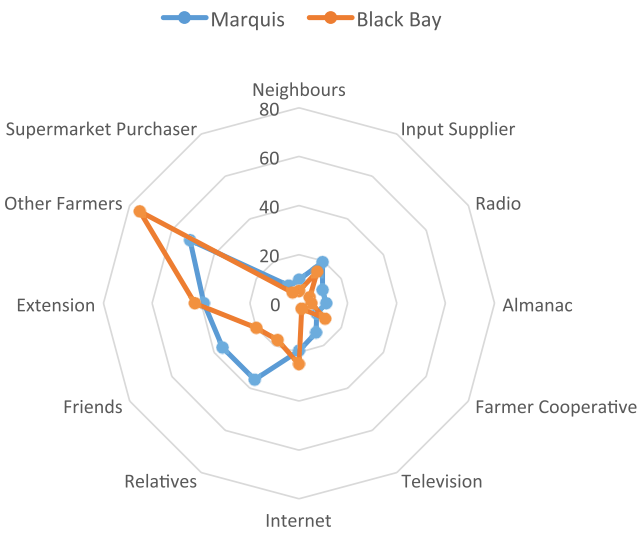


Fig. 2 Percentage of respondents who reported receiving new agricultural knowledge from different knowledge sources showing the important role played by 'peer farmers' relative to extension officers in both communities

In focus group discussions, farmers raised a wide range of issues that had implications for their level of interest in particular innovations. Of primary focus were challenges related to finding markets to sell their perishable produce, growing incidences of pest infestation, theft, and difficulties accessing labour. Of these challenges, there was wide consensus that a lack of domestic markets was the primary challenge that limited their ability to produce and innovate. More specifically, participants identified inconsistent supply of inputs and highly variable prices as challenges arising from the small domestic market, the large number of producers, lack of contracts (based on the small size of producers) and limited coordination among farmers. At certain times of the year, such as the dry season from January to May (called "*kawenm*" by farmers in *Kweyol*), there are optimal conditions for growing crops such as tomatoes, cucumbers and watermelon, resulting in seasonal over-production and drastically lowered prices. While participants acknowledged that this situation proved detrimental to all farmers, there appeared to be an inability

or unwillingness to formally organize and coordinate production. This situation suggests that greater communication among farmers will be required in order to foster a level of collective action in the form of voluntary coordination of production planning. When asked why the efforts of the Ministry of Agriculture to develop formal production scheduling plans to reduce risk and curtail overproduction had failed, farmers voiced concerns relating to low trust, and indicated their dissatisfaction with the associated risks to their livelihoods (without any means to ensure compliance by Ministry officials). As explained by one Black Bay farmer in reference to the short-lived production scheduling plan initiated in the late 1990s:

> "they're asking you to take risk that they are not taking themselves"

These risks were generally viewed as resulting from the ease with which the entire production plan could be undermined by noncompliance by any party. In the absence of formal contracts and production planning, the clear preference of the farmers we interviewed was for them to continue their production scheduling informally by observing the crops and volumes being planted by the other farmers in the area and availability at the farmer's market and supermarkets.

Ego-centric network analysis

Figure 3 presents the frequency distribution of "size" and "ties" in the social networks of farmers surveyed in Black Bay and Marquis, revealing key differences in the number of links between farmers that supported interpersonal knowledge networks. Our sample of Marquis smallholder farming households comprised almost double the "size" and "ties" of our Black Bay sample. Table 3 shows the correlation between measures of social capital (direct links with other farmers in their community - "size" and indirect links among alters - "ties") and self-reported innovation. These findings show a stronger positive relationship between respondents who self-reported as "recent innovators" and "size" .406 (.000), and "ties" .491 (.000), and those who self-reported as "past innovators" and "size" .397 (.000), and "ties" .404 (.000), suggesting that the larger the farmer's network of indirect connections (friends of friends), the greater the likelihood of them innovating.

Socio-centric analysis of interpersonal agricultural knowledge networks

The number of respondents (nodes) per community (k) were 40 in Black Bay and 72 in Marquis (Table 4). Our findings show that the average degree (the average number of connections between actors in the network shown graphically as the number of lines connected to each node) was 4.45 in Black Bay and 6.58 in Marquis. In each network, there are (k * k-1) number of total possible ties (without calculating self-ties), with 1560 total possible ties for our respondents from Black Bay and 5112 for the Marquis data. Out of this these total possible ties, respondents in Black Bay reported only 62

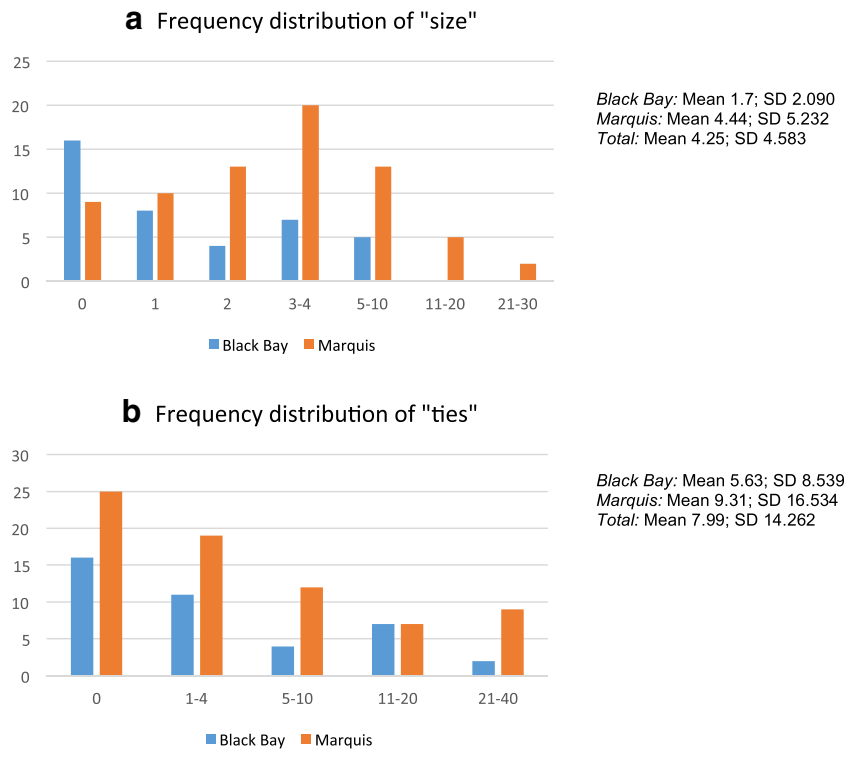


Fig. 3 Frequency distributions of (**a**) "size" and (**b**) "ties" for Black Bay and Marquis. Mean "size" and "ties" in Marquis were almost double that of Black Bay

Table 3 Correlation between ego network metrics (size and ties) with innovation adoption

Independent variables	Recent innovation	Past innovation	Innovation (combined "recent" and "past")
"Size"	.406 (.000)	.397 (.000)	.471 (.000)
"Ties"	.491 (.000)	.404 (.000)	.481 (.000)

'knowledge received' ties, and 59 'knowledge shared' ties; corresponding values for Marquis were 107 and 102 ties. In Marquis, "kinship ties" comprised the largest network component (268) unlike Black Bay where knowledge ties were largest. Network density (the proportion of all possible ties against those that are actually present) was 11.4 % in Black Bay and 9.3 % in Marquis, indicating that information diffuses relatively slowly among nodes in both networks, but this measure may mask community variations associated with the quality of interpersonal ties (Scott 2000). The distance measure considers how the actors are embedded in the network by looking at the number of links that separate them. For example, two adjacent actors have a distance equal to one. This means that in one step, information can go from one farmer to the other. In contrast, if A tells B, and B tells C (and A does not tell C), then farmers A and C are at a distance of two. Where distances are great, it may take a long time for information to diffuse across a population. In our case studies, average distance measures were 2.610 in Black Bay and 2.365 in Marquis, again suggesting that there are more than two people on average separating information diffusion from one farmer to another in the network.

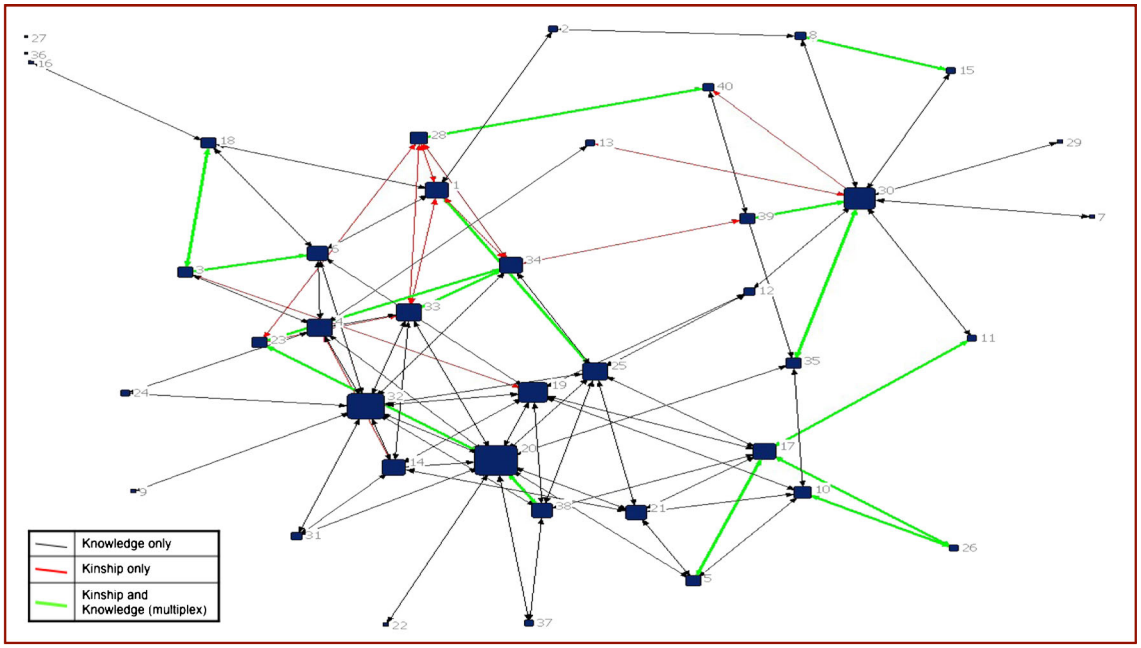
Figure 4 graphically depicts the social structure of the smallholder farmer knowledge networks of our respondents from the Black Bay (4a) and Marquis (4b) communities. In each figure the nodes represent respondents and the lines the relation between two nodes. To help clarify the "strong ties" in each network, line colours were used to show the overlap of relations. It should be noted that while Fig. 4 shows two knowledge networks of dissimilar sizes, what is more important is their structural differences. We found that by mapping the structures created by these different kinds of relationships (kinship, knowledge), we are able to identify different dimensions of social capital operating in the two case study networks. The knowledge network of our Black Bay respondents (Fig. 4a) consists of more bridging social capital measured at 31 % of overlap between knowledge and kinship. These "weak ties" connect different groups of people who do not share family bonds. In contrast, the knowledge network of the Marquis respondents (Fig. 4b) consists of higher bonding social capital, or "strong ties" measured by 61 % of overlap between knowledge and links to family members. The intersection of knowledge and kinship relations in the Marquis data results in a more centralized network dominated by a few central nodes connected by family ties.

Discussion

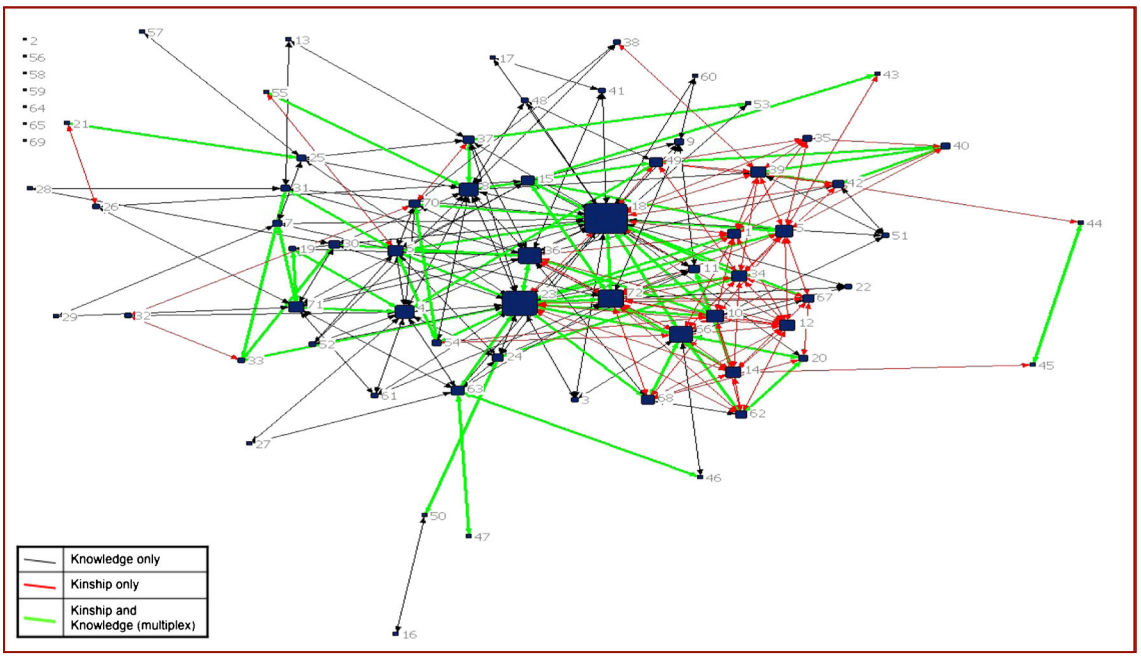
Over half of our survey respondents reported farming as being their only source of income. This situation is likely to make them vulnerable to shocks resulting from either internal or external factors. In the case of Saint Lucia, smallholder agricultural livelihoods are often based on highly vulnerable production systems creating 'poverty traps', generally characterized by a lack of connectedness and low resilience (Carpenter and

Table 4 Network summary data for Black Bay and Marquis

Network characteristics	Black Bay (40 nodes)	Marquis (72 nodes)
Types of ties found between respondents	No of ties	No of ties
New farming knowledge shared	59	102
New farming knowledge received	62	107
Kinship	53	268
Support requests	33	68
Potential support	50	102
Friendship	45	64
Average degree	4.450	6.583
Density	0.114	0.093
Average distance	2.610	2.365



a Black Bay



b Marquis

Fig. 4 Depiction of multiplex relations and overlap of knowledge shared, received and kinship ties in the knowledge networks of (**a**) Black Bay-40 nodes; (**b**) Marquis-70 nodes. Node sizes were adjusted by degree centrality to highlight the key nodes in the network

Brock 2008). This situation creates a significant challenge for smallholder agricultural policy in Saint Lucia and points to the need to foster greater trust and interaction among social actors (farmers) and institutions in the agriculture-food system. More specifically, there is likely to be a need to help smallholders better connect across the system in order to foster their capacity to adapt in the face of change and work collectively to address common problems (Carpenter and Brock 2008). Issues that undermine such adaptive capacity include: limited formal education, small farm sizes (<2 acres or .8 ha), producing at under-capacity, low trust, and informal marketing arrangements, resulting in a relatively high degree of household vulnerability

to shocks. The following quotes provide some insight to the situation facing smallholders in our study area:

> " … anything that I can plant, I plant…once I can make a dollar, so long it comes to my mind, I plant,… whether I make something out of it or I make nothing out of it, I am just trying something" (female farmer Marquis);
> "Well sometimes even though you know that there is a glut, there are not many things that you can plant and there are so many farmers. And you yourself you have to live, you have children you have your family to feed. So sometimes, you just have to plant it you know" (male farmer Black Bay).

Social relationships have been identified as performing a critical function in building (and limiting) adaptive capacity in smallholder farming systems (Pretty 2003). According to Norris and Stevens (2007), if farmers have resilient social supports, then it is likely that they would be used in times of uncertainty or resource limitations. Pretty et al. (2011) further suggested that sustainable agricultural intensification in low-yield areas (of Africa) will depend upon developing new forms of social infrastructure among smallholder farmers, likely involving the leveraging of their social capital in support of adaptive capacity in resource-scarce settings (Pretty and Ward 2001).

Our socio-centric analysis generally supported these observations, indicating that the presence of interpersonal agricultural knowledge networks supported the production capacity of smallholder farmers in both communities. The characteristics of these networks were quite different, likely reflecting the particular social-ecological characteristics of the community and supporting the need for context-specific approaches to agricultural extension and innovation (Hellin 2012; Wood et al. 2014). For example, the farmer knowledge network in Black Bay (Fig. 4a) appeared to be based largely on bridging social capital with kinship playing a relatively minor role. Such bridging social capital is known to provide sources of new information (Granovetter 1973) and can facilitate the diffusion of innovation (Sabatini 2009; Scott 2011). In Marquis, the knowledge network (Fig. 4b) was based more directly on bonding social capital, known to foster group identity and cohesiveness, but be less responsive to externally driven innovation and change processes (Burt 1995; van Rijn et al. 2012). Despite their differences, both knowledge networks can be seen as performing a critical function in the smallholder agricultural innovation system, by providing a trusted means to support innovation, and facilitate farmer knowledge exchange beyond what is available through the formal institutions of government.

Not only did our findings reveal that respondents employed social networks to better connect with each other, but that new knowledge sourced from interpersonal networks was generally considered of greater importance than that provided by the state-run agricultural extension services. While the results of our exploratory study are limited by the fact that we did not focus on a particular innovation and its diffusion process, they do support future efforts to do so. Our survey results also indicate that there may be a declining importance being placed on state-led agricultural extension services compared to 'peer farmers', and this is another area that would benefit from targeted research in the Caribbean context. Ganpat et al. (2010) highlighted a number of factors that might explain the limited effectiveness of formal extension services in the Caribbean, including: 1) weak linkages between agricultural research and education; 2) limited coordination of limited resources; and 3) inadequate adaptation of the institutional structures to meet existing needs and resource limitations. Recent research in Jamaica has highlighted the importance of shared local knowledge among smallholder farmers to their adaptive capacity (Campbell and Beckford 2009; Gamble et al. 2010). By experimenting with different approaches to agricultural extension services to foster peer-to-peer interactions and reciprocal knowledge flows between farmers, the interpersonal and procedural trust required for collective action may be enhanced (Hellin 2012; Schroeder et al. 2013; Yang et al. 2014).

Despite differences in the dimensions of social capital that comprised the knowledge network in our two case studies, the self-reported level of innovation among respondents in each community showed no significant difference. Egocentric analysis which was designed to capture the social networks of our sample of individual smallholders showed that although the direct links to other farmers in the network were significant in farmer self-reported innovation, the combined effect of the direct and indirect links were more significant. These results suggest that not only is bridging social capital within the knowledge network potentially positive for innovation, but the links between alters or "friends of friends" in the network is also important. This finding is supported by van Rijn et al. (2012) who suggested that the larger the network of adopters (direct and indirect links), the greater the likelihood that farmers would adopt innovations due to increased knowledge, access to resource and sources of support (see also Wossen et al. 2013).

The lack of significance in self-reported innovation between respondents in the two communities despite wide variabilities in their ego-centric social networks and the differences in the provisioning knowledge networks provides an interesting result. One possible explanation for this situation is that the farmers are able to receive support that influences their self-reported adoption of agricultural innovation through different mechanisms and types of interaction in each community. For example, in the case of Black Bay, farmers are likely able to share knowledge and work together with more diverse but fewer farmers, to achieve shared outcomes through regular formal and informal gatherings at the cooperative (including annual meetings, committee meetings, weekly trips to the office to deliver harvested crops targeted for hotels, workshops planned by the Ministry of Agriculture to address topical issues in

agriculture, and projects being undertaken through the cooperative by donors). In contrast, the Marquis farmers were likely accessing new agricultural knowledge through larger numbers of interpersonal ties comprising primarily family-based interactions that generally require greater personal investments of time, more deliberate interaction with more people and social expectations of reciprocity. As noted by Granovetter (1973), these "strong ties" are a costly investment because of the amount of time social actors need to spend together in order to foster and sustain an emotional connection, intimacy and commit resources to reciprocity of exchanges. Our findings may suggest that farmers in Marquis have less time available to participate in other activities. In contrast, farmers of Black Bay with their knowledge networks based on bridging social capital function through "weak ties" fostered by the operations of the cooperative and likely have more time and resources available for innovation. There are other potential disadvantages to the farmers of Marquis where, despite bonding social capital being helpful for the creation of favorable community conditions, 'network closure' can develop (Burt 2000). In the context of our two case studies, while social capital appeared to play a generally equalizing role in fostering innovation in the absence of secure land tenure (Black Bay) and a lack of formal farmer organization (Marquis), more research is needed to look at the differences in capital investment required to achieve these self-reported innovation returns.

While social capital and knowledge networks differed in our two case studies, their existence highlighted some of the pathways available to formal institutions, donors, and NGOs working to enhance knowledge exchange in the resource-poor, smallholder agricultural systems common to the Caribbean. These knowledge networks, built on interpersonal trust, represent resources invested by individual smallholder farmers and their communities to improve communication and knowledge exchange. Recognizing the limitations in the existing agricultural extension services in Saint Lucia, we suggest that such interpersonal networks provide a potentially powerful and adaptive mechanism through which to interact with smallholder farmers and ensure better-targeted interventions. Previous research by Osbahr et al. (2010) evaluated four agricultural development projects in southern Africa and revealed the important use of interpersonal networks as platforms from which to build more formal organizations (maize collectives). This suggests that by better linking formal and informal interactions, governments may be able to foster more decentralized and synergistic knowledge production and exchange at minimal additional cost (see also Mikulcak et al. 2015; Rahman et al. 2015). Better identifying and working with interpersonal networks may also help policy-makers initiate more integrated responses that can link smallholder farmer social capital to the significant human and financial capital of governments, donor agencies, the private sector and NGOs.

Conclusion

Policy interventions designed to better support smallholder agricultural innovation systems in the Caribbean will likely require creative and decentralized governance approaches to facilitate knowledge flow and build interpersonal and procedural trust. The results of our comparative case study highlight the presence and nature of the interpersonal agricultural knowledge networks operating in two farming communities in the nation of Saint Lucia. Despite structural differences, farmers in both communities reported using their social networks to access new agricultural knowledge and innovate, noting that this was a more important knowledge source than state-run agricultural extension services. Socio-centric analysis revealed that in the Black Bay sample, the knowledge network was based more on bridging social capital, while in Marquis it was based more on bonding social capital, with implications for how farmers can and do access the knowledge they require to innovate in different contexts. Egocentric analysis of individual farmer social networks showed that although the direct links to other farmers in the network were significant for self-reported innovation (past and recent), the indirect links between alters or "friends of friends" were more significant. These results suggest that not only is bridging social capital within the agricultural knowledge network necessary to support system innovation, but the total number of links between smallholder farmers in the network is essential. Our findings support the view that by utilizing their social networks to increase their connection to a larger number of farmers, smallholders may improve their adaptive capacity to: 1) facilitate knowledge exchange; 2) increase access to resources, and 3) connect to sources of support. Despite the recognized equity challenges associated with social capital in the literature, it has a potentially significant role to play in improving smallholder agricultural system innovation in the Caribbean context, both at the individual and community levels. Our results provide important insight into how these often hidden and decentralized networks may present food security-related policy and programs with an important and adaptive informal mechanism through which to better reach and coordinate smallholders in the absence of other, more reliable, democratic institutions.

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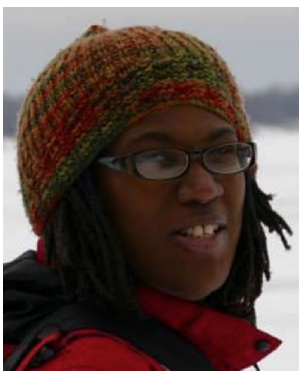

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