Can Farmer Networks Foster A Resilient Agriculture?

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ABSTRACT

This study aimed at determining the contribution of farmer networks (FNs) structure to resilience of agroecosystems. A total of 23 actors were surveyed using a census sampling method. Quantitative and qualitative data were collected using a mixed methods approach. Data were analysed using social network analysis and a deductive codebook. Findings revealed a cohesive group with high density (0.67), good arc reciprocity (54%), high transitivity (0.75). The network is cohesive and centralised, but periphery actors were more connected externally. There was positive correlation between frequency of communication and decision to change production system. Network is specifically for diffusion, but 90% of actors also adopted BMPs through social interactions. This study concludes that FNs can help in scaling up adoption of BMPs. FNs contributes to a resilient agriculture based on resilience principles of connectivity, encourage learning and experimentation and broadening participation. This is encouraging for policy to invest in FNs for BMPs adoption.

Keywords: Diffusion/adoption, Relational approach, social networks, socioecological systems, sustainability

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1.0 INTRODUCTION

Food remains an important element of human existence, yet 820 million people worldwide are hungry everyday (FAO, IFAD, UNICEF, & WFP, 2019). And another 2 billion people are food insecure (i.e. lack access to safe, nutritious food to meet their daily needs), 8% of this are in North America and Europe (ibid). This makes achieving sustainable development (SDG) goal – 2 to end hunger, achieve food security, improve nutrition and promote sustainable agriculture by 2030 (United Nations, 2015) a daunting task. Furthermore, world population is increasing at unprecedented rate and it is projected at 9.8 billion by 2050 (United Nations, 2017). In view of all of this, current belief by some experts is that curent food production rates may be adequate in meeting world food demand but that will require major transformations in the way food is produced (FAO, 2017). This is a departure from previous views that production needed to double to meet population growth. It can be argued that this assertion depends on the location. Besides, provision of food is not the only human needs met by agriculture.

More so, change in lifestyle such as more demand for meat-based diets, and industrial products have further increased pressure to increase agricultural production. This is partly responsible for modifications of farming systems to increase productivity at the expense of natural resources thereby degrading the environment (Nelson, Brummel, Jordan, & Manson, 2014). Agriculture is also a major contributor to climate change and environmental degradation from use of unsustainable farm practices. This further exacerbates the complexity of the operating context for agricultural production increasing its vulnerability to perturbations. Examples of unsustainable farming practices include, poor application of synthetic fertilizer which contributes to non-point source pollution of waterbodies, deforestation, tillage practices, use of fossil fuels for farm machinery. The effects are detrimental to agricultural production and it contributes to reducing the

capacity of the system to cope with shocks both specified and unspecified (Callo-Concha & Ewert, 2014). Shocks include extreme weather events, floods and droughts. To improve capacity of the agricultural systems to cope with shocks, production practices must be modified or changed. Admittedly, to transition to alternative farming practices that are sustainable takes time.

This envisioned transformations in agricultural systems requires concerted efforts of stakeholders (FAO, 2019). Farmers are key stakeholders in agricultural systems because they are involved to a greater extent in primary production and they deal directly more with the ecosystem and its services. Also, very importantly is that farmers often own the land and so are its primary steward. Rockenbauch & Sakdapolrak, (2017) believe that farmers are also land managers in addition to food producers. However, the change needed means that stakeholders need to unlearn unsustainable farming practices and learn beneficial management practices (BMPs). The process of switching to new practices is complicated with many factors intertwined. This include knowledge, financial and social factors.

Farmer knowledge is arguably the first step towards this transition. Carlisle et al. (2019) believe that knowledge-intensive farmer and agriculture that will reduce environmental footprint of agriculture. For example, making cropping system change requires adjustment of farm plan and operations in many ways. But the farmer must first be knowledgeable on what crops and other system elements which are compatible for this change, then decisions around how to begin. Is it with the whole farm or in sections as a start? Also, a crucial consideration is labour, what level of mechanization or manual labour? An entirely different type of machinery may be required or possibly a change to manual labour for some operations like harvesting.

So, to make this transition, farmers need support at various levels and one channel is through farmer networks (FNs). FNs are effective in scaling up diffusion of agroecological

technologies and they influence how fast farmers can adapt to change (Altieri, Nicholls, Henao, & Lana, 2015). For example, the methodology used by C*ampesino a Campesinao* in Mesoamerica boosts horizontal interactions in its networks to transfer and exchange information on agroecological-based adaptive strategies to farmers (Rosset, Braulio, Jaime, & Lozano, 2011). And it has been recorded as the most effective approach in scaling up diffusion.

In this study, a FNs refers to all the actors to whom a farmer is connected that provide support in the form of acquisition and diffusion of knowledge, information, innovation, and adoption of beneficial farming practices (Baumgart-Getz, Prokopy, & Floress, 2012). Actors include peers, advisers, researchers, and government agencies (Cofré-Bravo, Klerkx, & Engler, 2019). FNs can also be considered communities of practice. In communities of practice there is shared interest amongst practitioners who interact regularly to learn and as a result, relationships are developed (Wenger, 2016). There are many benefits of FNs which include their contribution to better management of natural resources through fostering of social learning (Keen et al. 2005).

So far, many studies on FNs in the literature have focused on its role in adoption of innovation and technology from an agricultural extension standpoint (Pape & Prokopy, 2017). Also, related is the application of social networks commonly in understanding natural resources management (Bodin, Crona, & Ernstson, 2006). However, exploring the potential of FNs in contributing to resilience of agricultural systems have not been done in the literature so far, at least to the researcher's knowledge. Therefore, the intent of this study is to explore and understand how FNs can contribute to resilience of agroecosystems through diffusion and adoption of beneficial management practices (BMPs).

1.1 Objectives

The motivation for this study is the recognition of the role which farmers play in shaping outcomes in agricultural systems particularly in unprecedented times like this in human history. The task of intensifying food production without further destroying natural resources for future generations to still produce food is huge. Therefore, the social part of the equation which includes farmers deserve perhaps more attention now because more focus has been given to the ecological and technological aspects in agricultural systems over time. The objectives of this study are as follows:

1. To understand how the structure and function of a formalised FNs can influence adoption of beneficial farming practices (BMPs).
2. To determine if FNs can contribute to the general resilience of agricultural systems based on principles of resilience.

2.0 LITERATURE REVIEW

2.1 Agroecosystems as Socioecological systems (SES)

Agroecosystem can be defined as an ecosystem managed with the intention of producing, distributing, and consuming food, fuel, and fibre (Connell, Walker, Abel, & Grigg, 2015). Its boundary is beyond the physical space for production, and it includes resources, markets and institutions nested at multiple scales. It is a man-made system for the purposes of producing food, feed and fibre. On the other hand, agricultural systems refer to larger scale considerations of agroecosystems while the latter may sometimes be used in reference to farm level or the landscape. Agroecosystem as socioecological system (SES) shows a complex interaction of social (human) and ecological (biophysical) systems in multiple ways (Berkes & Folke, 1998, Gardner, 2019). These interactions are often unplanned and unpredictable (Bacon et al. 2012, & Gunderson, 2000) and SES capacity to cope with changes is dynamic (Lengnick, 2015a). Agriculture is one of the most resilient human activities that has adapted over time with numerous changes in the food production landscape (Gardner, Ramsden & Hails, 2019). Technological advancements have contributed to adaptation through manipulation and/or replacement of natural ecosystems making it possible to produce food. But a continuous replacement of natural systems with agricultural systems could lead to a collapse of SES (Gardner, 2019). The issue is that agroecosystems have been managed as if they are engineered systems (Chapman et al. 2017). It is however unclear how long present man-made designed agricultural systems will support natural processes (e.g. nitrogen cycle) and ecosystem services for food production.

Moreover, agricultural production has more than tripled in the past five to six decades, mainly due to Green Revolution (FAO, 2017). This period has been characterised by the rise in use of technology such as high yield crop varieties, fertilizer use, expansion of agricultural land

and essentially the industrialization as well as extensive vertical integration of food chains. Consequently, this development has come at great cost to the environment with increasing incidences of extreme weather events and climate change at large. Scientific evidence suggest that current trajectory is unsustainable because we are approaching the point of planetary boundary . It is therefore unsurprising that discussions on alternatives and sustainable farming practices to enhance resilience of agricultural systems has taken front burner. In order to have any meaningful discourse on sustainable agriculture, it is necessary to consider the complexity of agricultural systems in light of its adaptive capacity and its embeddedness in wider sociological systems (Bacon et al. 2012).

2.2 Sustainable vs Resilient Agriculture and BMPs

According to Organization for Economic Co-operation and Development (OECD) and Brundtland Report, sustainable agriculture refers to agricultural production that is economically viable and does not degrade the environment over the long run (WCED, 1987 & OECD, 2003). Sustainable agriculture provides the fundamental framework for developing adaptive capacity through use of practices which are beneficial in regenerating and maintaining natural resources thereby enhancing overall response capacity of the system. Beneficial management practices (BMPs) include a wide range of farming practices that prevent degradation of the environment (terrestrial and aquatic) such as pollution, soil erosion (Mackay, Bennett, & Lefebvre, 2010). An example of its application is in prevention of non-point source water pollution (Akkari & Bryant, 2017) through nutrient stewardship. It is noteworthy to mention that suitability of BMPs depend on operating contexts at a given time. In this study, BMPs considered are targeted towards soil management (Chami, Daccache, & Moujabber, 2020). They are cover crops, strip or no till, soil amendments (manure, compost), crop rotation, windbreaks and erosion control.

Adoption of BMPs offers prospects at fostering sustainability and attempts have been made in using implementation of BMPs as targets in measuring or attaining sustainability in Canada (Mackay et al. 2010). But determining the extent of BMP adoption in Canada on a broad scale is difficult. This because there are different BMPs used for different purposes such as soil management, and integrated crop management (Chami et al. 2020). And farmers are not obligated to report them, BMPs are incorporated into environmental farm plans which are confidential. However, the projections in literature indicate a lot of opportunity for adoption rates to improve since it was rated at a medium range (Mackay et al. 2010) and it will be interesting to know if this has changed after a decade. The task is in scaling up the adoption of these BMPs, but this depends on several factors such as economic and social factors. In the adoption literature, farmer social associations and networks have been identified as one of the factors positively influencing BMP adoption through building individual farmer capacity in the form of knowledge (Baumgart-Getz et al. 2012).

Time is another factor that influences adoption and this can be described using the adoption S-curve i.e. rate of adoption (Rogers, 2003). It takes time for innovation to be disseminated (Young, 2009). Based on time, adopters are categorised on how quickly they adopt a technology: innovators, early adopters, early majority, late majority and laggards (Rogers, 1958, & Rogers, 2003). A modified classification is innovators, early adopters, late adopters and non adopters (Diederen, Meijl, Wolters, Bijak, & Van Meijl, 2003). The S-curve of adoptions indicates that 16% farmers may not adopt an innovation while innovators constitute 2% (Rogers, 2003) The innovators (initiators) are more involved in the innovation process and connected to external sources compared to the rest. Early adopters are the imitators, they are more likely to adopt through association from perhaps being in the same network with the initiators (Maertens & Barrett, 2013).

But early adopters constitute 13.5% of the adoption process and perhaps more important than innovators because they are more integrated into the social system (FNs) than initiators who are more connected externally (Rogers, 2003). Also, they are already aware that change is needed and are comfortable changing as well as disseminating information to others who highly regard them.

Other factors influencing farmers adoption of BMPs can be found in reviews by Prokopy et al. (2008) Akkari & Bryant, (2017), Liu, Bruins, & Heberling, (2018) and Mishra et al. (2018). To improve the chances of adoption of BMPs, Sumane et al. (2017) emphasize the role of new forms of knowledge base coupled with new content and new processes of learning. Farmers sharing experiences can pass for new process of learning. Though their knowledge is informal, local and context specific, it is often as valuable as scientific knowledge. FNs is an established platform for information sharing, and so it can be leveraged for diffusion of BMPs (Lengnick, 2015a). Rogers, (2003) identifies interactions occurring within social systems such as FNs as the fourth key element (others are -innovation, communication & time) for adoption. FNs determine boundary for diffusion and the actors can influence one another. Therefore, by facilitating information sharing, knowledge and innovations, cooperation and connectivity among specialized components of socioecological systems, FNs are promoting sustainability (Levy & Lubell, 2018).

Farmers manage agroecosystems for resilience at varying degrees whether they are aware or not. To better understand issues around sustainability of agricultural systems, it is beneficial to approach it from a resilience perspective because it will provide insights to features and processes relevant to sustaining agroecosystems (Connell et al. 2015). A resilient agriculture can be described as the capacity of agricultural systems to respond or cope, recover and adapt to shocks while maintaining its function (primarily food production), ability to learn, self-organize and

innovate (Lengnick, 2015b). The behaviour of resilient agricultural systems depends on some qualities. They are namely diversity, modularity, feedback and high levels of financial, human, social and physical capital (Lengnick, 2015a).

The degree of adaptive capacity of agricultural systems is determined by the aforementioned qualities. From a social perspective, the system can only be resilient if there is diversity in function which buffers the response capacity. A diversity of farmers involved in different farming enterprises supports the system in case of a shock like drought. Because high functional diversity supports response capacity of the system (Lengnick, 2015b) by ensuring that other types of foods are still available. This avoids a total collapse of the system. Also, presence of several groups interacting more within than between groups encourages resilience of the larger agricultural system. So, there is connection but not to the threshold where if there is for example misinformation or wrong farming practice, the scale and scope of spread is reduced. Another related quality is self-organization in the system in a way to allow balancing and reinforcing feedbacks. In addition, a resilient agricultural system has capital (social in this context) reserves to aid recovery and restoration should any perturbation occur (Lengnick, 2015b, & Carpenter et al. 2012). Social and community memory built through FNs where personal experiences, skills and other kinds of support encourages resilience. It can be inferred from these qualities some relationship between sustainable agriculture and resilient agriculture.

The common feature between sustainable and resilient agriculture is that both arise from interactions between components of agroecosystem. Arguably though, the difference between the two concept is that resilient agriculture is the property of the system indicating quality while sustainable agriculture is the tool for achieving it. To put it differently, resilient agriculture is a desirable state while sustainable agriculture is a pathway. The logic in resilient agricultural systems

thinking is the recognition that change is inevitable and therefore, the system must be designed in a way to accommodate change (Gardner & Ramsden, 2019). Chapman et al. (2017) explains this thinking further as recogninzing that the system has multi-causality of change and it is unpredictable as regime changes, the effects are cummulative, it occurs at different scales simultaneously and it is teleconnected in space and time. The implication is that mechanisms such as networking and learning, behaviour, self-organization must be built into the system to cope. Resilience thinking in agricultural systems is the rational way to approach designing these systems. It is necessary otherwise food options, the quantity and availabilty may be limited for future generations as a result of reduction in options available on how to produce food due to degraded environmental resources (Ramsden & Gibbons, 2019).

2.3 Resilience

A good way to begin a discourse on resilience is to stress that any resilient system requires a threat, disturbance or shock to its functioning or survival as a test (Bergström & Dekker, 2014). Resilience can be defined as the capacity of an ecosystem to respond in a way that offsets perturbation and disturbance through resistance to damage while quickly recovering from same (Holling, 1973). Socioecological resilience focuses on people and nature as interdependent systems (Folke et al. 2010). It refers to the capacity of these interdependent systems to adapt or transform during unexpected change and in ways that continue to support human well-being (Folke, Gary & Kofinas, 2009, & Biggs et al. 2015).

There are two kinds of resilience, the specified and general resilience (Lengnick, 2015a & Carpenter et al. 2001). Specified focuses on managing specific events or stressors on an aspect of the system to identify known and possible thresholds. Whereas, general resilience refers to the capacity to absorb all types of disturbances; i.e. a general coping of the system. The definition of

general resilience is a consideration of social-ecological system's ability to adapt or transform as a response to unfamiliar, unforeseen events and extreme shocks (Folke et al. 2016). General resilience can also be viewed as adaptive capacity (Walker & Salt, 2012) and this is the focus of this study. Connell et al. (2015) further the definition as the ability to build and increase the capacity for learning and adapting. In agricultural context, resilience (general) lies in the capacity of the farmer to navigate socioecological interactions that are unpredictable, but necessary in day to day farm functions (Darnhofer et al. 2016). Also, from a social perspective, the ability of farmers to organize themselves in conjunction with other stakeholders is an indicator of a resilient agroecosystem (Cabel & Oelofse, 2012).

In order to operationalize resilience, considerations of best approach arises: measurement or assessment? Since resilience is a trait of complex adaptive systems, it cannot be easily measured because using standardized tools to measure it quantitatively and rigorously is not feasible (Quinlan, Berbés-Blázquez, Haider, & Peterson, 2016). Rather using an assessment approach is more feasible since it seeks a deeper understanding of the dynamics of the system. So far, the concept of resilience is common in several disciplines but the closely related disciplines relevant to agriculture are ecology, psychology and disaster management (Lengnick, 2015b). The reason being that methods of assessment have been derived in these disciplines in a way that accounts for dynamics of complex adaptive systems. Resilience can be more qualitative and something to be optimised than quantitative (Levin et al. 2013). It is a difficult concept to measure due to its multidimensional nature (Darnhofer et al. 2010). Rather than look for indicators to measure variables in resilience research, Carpenter, Westley, & Turner, (2005) suggest use of surrogates which can be useful proxies for assessing resilience in socioecological systems. Looking out for system behaviour can be an indirect indicator of resilience (Holland, 1998). In addition, assessing

resilience is complex because it is contextual, place-based and depends more on the specific aspects considered (Walker & Salt, 2012).

As part of assessing resilience in socioecological systems, Biggs et al. (2012) proposed seven principles. These principles are interdependent and co-occur covering both social and biophysical components of SES. Resilience is a function of these two groups. However, four principles were more relevant in answering this research objective. On the social side of agricultural systems, farmers are considered as lower level agents and the resilience of this system is even more a function of the behaviour of the lower level agents (Gardner, 2019). Similarly, Darnhofer et al. (2010) underscore the need to focus on the human (farmer) side of farm resilience, the social domain in resilience deliberations. The farmer role is crucial since the decision making on farms is directly affected by them. The outcome for any agroecosystem is dependent on governance which influences interactions between social and ecological systems.

For effective governance of resilience, Lengnick, (2015b) suggest that scale of focus be defined. In addition to the focal scale is the need to consider other scales beneath and immediately above it. This is because of the nestedness of resilience and being a behavioural trait, impact on one scale affects other scales i.e. cross scale effects (Carpenter et al. 2012, & Cabell & Oelofse, 2012). The implication is multidimensional structure operates simultaneously at the various scales and hierarchies, from farm (micro), regional (meso) to global (macro) scales (Bergström & Dekker, 2014). For example, Chapman et al. (2017) illustrates how global agri-food systems essentially run on demand of food products which are produced locally while at the local level farmers are bogged with taking decision to align with the pressure from upper scales. And in between these scales may exist other levels depending on location and context. Decision-making for farmers include how to effectively manage biophysical aspects of the agroecosystem like soil

nutrient management and appropriate cropping system based on resources at his disposal. This is an enormous responsibility. Therefore, to cultivate general resilience of agricultural systems, building farmer capcity and the overall social response capacity requires significant considerations (Lengnick, 2015a).

2.4 Farmer Networks (FNs)

FNs defined loosely describe a group of farmers who are together to learn better ways of farming usually with one or more advisors supporting the process (Chapman & Kyveryga, 2016). For formation of FNs, it is common to see these groups emerge more exogenously than endogenously and as such they are some basic guidelines and manuals on how to form FNs (example see Matthewson, Fery, & Powell, 2014). However, it is important to note that not all social networks or FNs are created equal (Newman & Dale, 2005). FNs are usually established for specific objectives such as demonstration and field trials. The purpose for formation, organizational structure and funding influence how it functions. And as such, different structures have different implications on governance particularly for socioecological systems management (Matous & Todo, 2015). In the US, FNs have evolved over time for several functions from partnerships with research institutions, universities, non-governmental organizations and government (Chapman & Kyveryga, 2016). An example is Indiana On-Farm Network (now INfield Advantage) funded by Indiana State Department of Agriculture to help farmers understand nitrogen management (Pape & Prokopy, 2017). With these set-ups, partners provide funding in form government grants, sponsorships, and community funds where local communities support local farms (Matthewson et al. 2014). Another funding model is members pay dues to sustain operations of the network.

Whatever the purpose of FNs, social interactions occurring within the group form a social network. A social network comprises the individual members (nodes) in a group and the interactions (ties) that occur between them (Maertens & Barrett, 2013). Embedded within these interactions is a flow of knowledge which is a central conduit by which social networks influence adoption of new technology (Ramirez, 2013). Classification of social networks can be influenced by governance structure (McCann et al. 2016). Provan & Kenis (2008) postulate that network governance structure can be informal or formal. Formal networks are organized, well-structured with defined members and a clear purpose (Monge & Contractor, 2003) whereas informal networks are unstructured and non prescriptive, individuals determine their interrelations on their terms without organizational prompting (Krackhardt & Hanson, 1993). None is better, it all depends on circumstances of creation and other factors.

Network structure affects process or function which in turn affects resilience of SES. This has been studied extensively in natural resources management (Bodin et al. 2006, & Bodin & Crona, 2009), aquaculture and fisheries (Joffre, Poortvliet, & Klerkx, 2019, & Joffre, De Vries, Klerkx, & Poortvliet, 2020), adoption and diffusion of innovation in agricultural production (Levy & Lubell, 2018, Maertens & Barrett, 2013, Aguirre-lópez et al. 2020, Díaz-José, Rendón-Medel, Govaerts, Aguilar-Ávila, & Muñoz-Rodriguez, 2016, & Pape & Prokopy, 2017). Informal knowledge shared in FNs helps BMP adoption and contributes to constructing alternative pathways towards strengthening agricultural resilience (Knickel et al. 2018). Also, ability to access information, learn and act accordingly, is a major component of resilience (Vogt et al. 2015).

The mechanism of how FNs work is an important point to highlight. Social learning is an underlying tool which flow of information and knowledge enhances. Social learning is defined as a process whereby changes which occur in an individual to the benefit of wider socioecological

systems as a result of interactions with other people in a group (Reed et al. 2010). Social learning creates opportunities to make changes which are demonstrated through actions to adapt to new situations. Resilience of socioecological systems depends in part on their social learning capacity (Davoudi, Brooks, & Mehmood, 2013). FNs provides multiple sources where farmers can learn from one another. This helps in overall innovation and diffusion of practices (Aguirre-lópez, Díaz-josé, & Chaloupková, 2020) and it strengthens resilience at different scales.

FNs is also crucial in driving experimentation which contributes to enhancing adaptive capacity of agricultural systems. There is opportunity to participate informally with other farmers to learn and develop other skills such as leadership (Chapman & Kyveryga, 2016). This informal interactions and experimentation enable a farmer to adapt to uncertainties and changes in policies, prices, technologies, climate gained from insights of personal experiences (Cundill, Leitch, Schultz, Armitage, & Peterson, 2015). They also develop necessary skills and attitudes together to adapt in the process. FNs is a safe place to learn compared to learning from extension officers who they often mistrust (Šūmane et al. 2018). It explains why often times sustainable agricultural development is quicker through informal learning compared to formal learning i.e. extension services (ibid). This is because FNs offer alternative learning mechanisms via co-learning and mutual support. Learning and implementation occurs at individual level, but the impact reverberates up to the system level.

In addition, adoption of BMPs is part of what farmers learn from one another in FNs. A survey of farmers who belong to formal networks vs. non-network members showed that network members changed nitrogen management strategies as a result of participation in networks (Pape & Prokopy, 2017). Apart from belonging to a network, the length of time in a network also has a positive influence on adoption rate. Examples of the BMPs with higher adoption rate for network

members include cover cropping, vegetated riparian buffers and variable rate of fertilizer application. Some of these practices can also be classed under agroecology. Kansanga et al. (2019) has established a relationship between social capital and adoption of agroecological practices in farmer to farmer peer networks in Malawi. However, not all FNs are effective for diffusion and adoption of BMPs. In order to be effective, Pape & Prokopy (2017) suggest that there should be diversity or heterogeneity of farmers, inclusion of professionals (e.g. crop consultant and veterinary doctor), and more frequent meetings.

The structure of FNs will provide insights to how BMP adoption is affected and its connection to resilience. Two levels of consideration are required: whole network and individual actors (the nodes). At whole network level, the structure and relational patterns (interactions) are the key features to describe and analyze a network (Borgatti, Everett, & Johnson, 2013). Structural characteristics of a network are influenced by relational patterns which affects its social functions (Bodin & Crona, 2009). Social functions of networks are influenced by its features which include heterogeneity, adaptive capacity, trust, and learning (Bodin et al. 2006). This suggests that there is a relationship between structure and process. Relational patterns are made up of ties and the arrangement of these ties determines the structure. The shorter the path between nodes, the better the communication, diffusion and flow of other resources (Vishnu, Gupta, & Subash, 2019). Highly dense relational ties are beneficial for joint action and other kinds of collaboration, creation of knowledge, and increased amount of information within the network. But Sandström & Carlsson (2008) argues that highly dense ties can sometimes be detrimental to innovation by limiting flow of knowledge from distant nodes and can hinder heterogeneity of actors.

The level of network cohesion describes relational pattern and an understanding of the behaviour of the whole network. Table 1 summarizes key whole network measures and how the

resilience principle directly or indirectly affected. Absence of subgroups depicts a strong network which hangs together (Bodin & Crona, 2009). This enables rapid mobilization and diffusion of resources across the whole network. In addition, network size (i.e., number of individuals in the network) and heterogeneity (i.e., how diverse those actors are with respect to attributes) determine the rate of exposure to diverse sources of information. Consequently, a large and heterogenous can access information, knowledge and other resources faster than a small and homogenous network (see Table 1). It is therefore essential to consider diversity of actors including those outside the network (André et al. 2017).

Table 1 FNs structural measures at whole network and individual levels, their description, features/functions they affect and the related resilience principle Adapted from Bodin, Crona, & Ernstson, (2006) and modified.

Whole Network Level

Measure	Description	Feature/Function	Resilience principle
Density	the number of ties present in a network to the number of possible ties or actual ties divided by the number of potential ties in the network	Social memory: Collective memory/experiences to be used in time of change and uncertainty (McIntosh 2000, Folke et al. 2003)	L&E, CT L&E
		Heterogeneity: actor diversity broadens collective knowledge base and increase the capacity for innovation and maintenance of different knowledge systems and frameworks for interpretation (Folke et al. 2005, André et al. 2017).	M.C, BP L&E
		Redundancy:	

		Provides buffering capacity in case of loss (Janssen et al. 2006). <u>Adaptive capacity:</u> New knowledge and/or changing conditions require adaptive capacity and innovation to meet new needs (e.g. Gunderson 1999, Walker et al. 2004) <u>Trust:</u> Co-management is facilitated by trust among actors (e.g., Olsson 2003, Sumane et al. 2018, Leitch, Cundill, Schultz, & Meek, 2015)	L&E, MC, BP
Transitivity	indicates the transitive relationships in a network i.e. friends of friends as friends	<u>Heterogeneity:</u> Strongly connected relationships can hinder heterogeneity	MC, L&E
Reachability	In a connected network all pairs are reachable (Wasserman & Faust, 1994)	<u>Social memory:</u> Collective memory/experiences as reserve (McIntosh 2000, Folke et al. 2003) <u>Learning:</u> Access to many actors from whom knowledge and information can be amassed or to whom it can be distributed (e.g., Oh et al. 2004). <u>Adaptive capacity:</u> Collective action requires multiple actors to collaborate, (Steel and Weber 2001).	L&E L&E

Centralization	group centralization indicates variability or spread and distribution of nodes in a network into core and periphery actors (Wasserman & Faust, 1994).	Learning: high centralization, fewer learning and experimentation (Leavitt 1951, Shaw 1981). Adaptive capacity: Higher coordination ability and rapid response during perturbation (Leavitt 1951)	L&E
Reciprocity	indicates mutual sharing or exchange of information and other resources in the network.	Trust: A high degree of separation among groups can undermine the development of trust (Borgatti and Foster 2003) Adaptive capacity: Mutual exchanges can build capital which is necessary to cope and restore functions in crisis (Lengnick, 2015b)	MC, L&E MC

Individual (Actor) Level

Measur	**Description**	**Feature/Function**	**Resilience principle**
Betweenness centrality	- measures the contribution of each node in minimizing the distance between nodes in the network (Freeman, 1979). Mediator role node, gatekeeper, bridge	Heterogeneity: some number of subgroups is required to maintain it Learning: presence of bridge brings new ideas and supports strong links for tacit knowledge transfer (e.g., Reagans and McEvily 2003) Redundancy: A high degree of betweenness of single actors makes the network vulnerable to fragmentation	MC, BP, L&E MC MC, L&E, BP

		should these actors disappear (Borgatti 2003) Trust: A high degree of separation among groups can undermine the development of trust (Borgatti and Foster 2003) External ties: sector decisions are influenced by social actors with external ties (King, 2000, & Biggs et al. 2012, Cofré-Bravo et al. 2019, & Matous, 2015)	BP, L&E
Degree centrality	indicates the number of ties that a node has (Freeman, 1979), indicates sender and receiver for asymmetric network	Resource flow: As source or sink, facilitate information flow Learning: Initiate or facilitate ideas	MC L&E

L&E – Learning and experimentation, BP – Broaden participation, CT- CAS thinking, MC – Manage connectivity

At the individual actor level (nodes), actor position affects the governance process in terms of prominence and influence (Wasserman & Faust, 1994). Location of actor is helpful in determining an individual's degree of influence. This is measured as centrality which is expressed in degree, closeness and betweenness (Bodin & Crona, 2009). The significance of these actor traits is the predictability in behaviours. Central and peripheral actors are more predictable in their behaviour towards other actors whereas actors with intermediate number of ties are less predictable. In view of this structural characteristics at whole and individual levels (see Table 1), diffusion and adoption of BMPs can be studied in FNs considering individual node attributes because they contribute to the overall functioning of the network (Bodin & Crona, 2009). More so, functions of FNs can promote resilience in agricultural systems (Levy & Lubell, 2018).

2.5 Conceptual Framework

The fundamental concepts framing this study are socioecological systems (SES), social network structure, sustainable agriculture and resilience. Agricultural systems are (SES) comprising biophysical and sociological aspect. The sociological (human) aspect and its interactions impact adoption of BMPs which is an approach of sustainable agriculture, and it contributes to the resilience of agricultural system (Figure 1). In governing SES, farmers who are key component of the sociological make decisions on what methods and practices to use for food production. One of such decisions is the use of beneficial management practices (BMPs) to the ecosystem and contextually the soil. Functions of FNs which include building trust, heterogeneity contribute to then general resilience of agricultural systems under the principles presented. The four principles of resilience (Figure 1) considered are chosen because they are more relevant to the objective of the study.

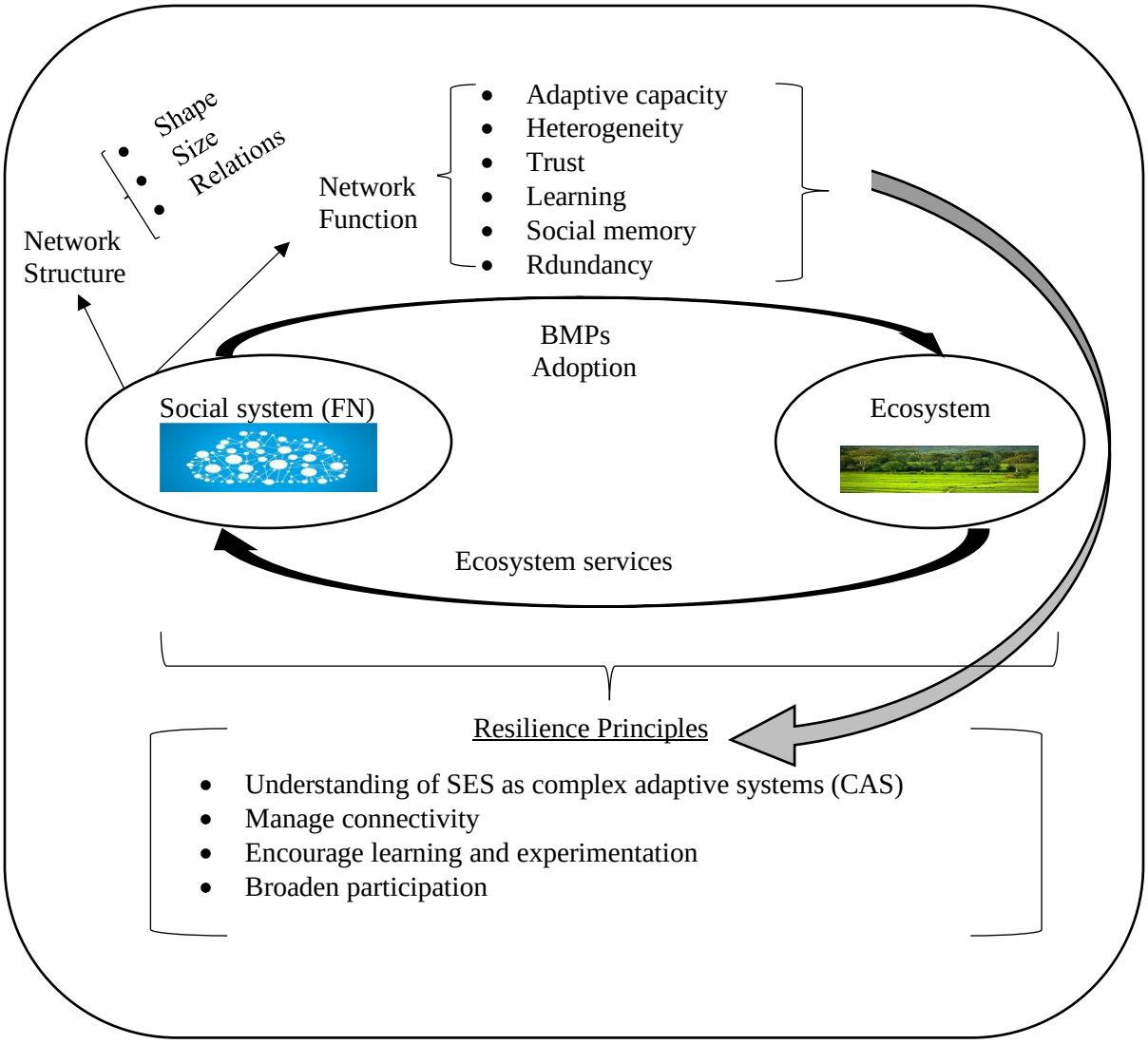

Figure 1: Conceptual Framework mapping the interconnectedness between FNs – (sociological system) and ecosystem (ecological system) as socioecological systems (SES) being managed by FNs through adoption of soil beneficial management practices. The functions of FNs contribute to the general resilience of agricultural systems under the principles listed

3.0 METHODOLOGY

This study used a mixed methods design approach which was sequential and explanatory (Hollstein, 2014). A case study method of inquiry was used to gain more insights on FNs. The focus of this study was in two parts in line with the two objectives of the study. First, an understanding of the structure of FNs was undertaken with primary data collected via an email survey and an online semi-structured interview recorded verbatim using Lifesize conference call software. In the second part, an assessment of FNs was done based on evidence gathered from data collected to determine if they contribute to the general resilience of agricultural systems.

3.1 Description of Case study

By way of setting a context, it is important to provide a background on the case study. Ontario soil Network (OSN) began as an informal group of farmers who met in small groups interacting and learning about farming. A formal network status began in 2017 as the pilot year for early adopters of BMPs leadership program and a second round occurred in 2019. This 1-year leadership program aims at transferring knowledge from peer to peer. This program is open to all farmers in Ontario but typically about 40 farmers (early adopters) participate in the program with the hope of mentoring other farmers (late-adopters). As a farmer-led diffusion network, its specific focus is on increasing the adoption of beneficial management practices (BMPs) targeted at building the soil (Rural Ontario Institute, 2020). These practices include cover crops, minimum tillage and soil amendments. Retention rate of alumni from the 1-year leadership challenge is about 50%. In addition, although OSN is a farmer-peer network, the Rural Ontario Institute (ROI) is the administrative and project lead (Rural Ontario Institute, 2019). ROI is a publicly funded organization aimed at developing leaders for rural issues.

The OSN refers to participants of the one-year leadership program as early-adopters. The term early-adopters in the adoption literature is used for farmers who are the second after the innovators to adopt a new technology or practice (Diederen et al. 2003). Sometimes early adopters are trained by initiators who may be members of FNs. And hopefully, the early adopters eventually train the late adopters, or they adopt later on as information is disseminated. Typically, training farmers in a network to adopt a new practice is a maintenance strategy of FNs (Matthewson et al. 2014). But the OSN is running a leadership program not as a FNs maintenance strategy. Rather, it is focused on leadership skills development while relying on their experience as early adopters to diffuse soil BMPs. The farmers are not part of the OSN, they are already "experts" who have committed to disseminating information on soil BMPs to other farmers using any four methods such as field demonstration, social media and magazine publication to achieve this goal.

3.2 Methods

A mixed methods approach was used as outlined below.

3.3 Sampling

A complete census sampling method (Borgatti, Everett, & Johnson, 2013 and Knoke & Yang, 2008) of all members of the network was done to obtain detailed information of the population.

3.4 Data Collection

To compliment the census sampling method and to understand the whole network structure, a sociometric or complete network approach (Hanneman & Riddle, 2005) was used in collecting network data. Data were collected sequentially with the survey as the first stage followed by the interview. A questionnaire was used for the email survey administered by the coordinator of OSN using Qualtrics software. Contained in the survey link was a consent form explaining the

purpose of the data collected, how it will be stored and used, and their non-obligation to partake in the study. The questionnaire was a modified version of an existing instrument used in previous study approved by Brock University Research Ethics Committee (File No. 18-161).

The range of questions in the survey included non network and network questions. For non network questions, a combination of quantitative and qualitative data were collected. For example, how many meetings do you attend, how happy are you with the soil health management practices you have implemented in the past and the type of community involvement. Network data gathered was through either a roster or free recall technique (Wasserman & Faust, 1994) depending on the survey question. Examples of questions where roster technique was used are, "What is the nature of your communications with this person?", "is there a farmer you look up to within the OSN?", "Are your communications generally positive, negative, or neither (neutral)", "What is the nature of your communications with this person?" (see Appendix A). The free recall technique was used for all other network questions pertaining to actor influence from outside the network e.g. "Since joining the OSN, who from OUTSIDE the OSN has influenced your decisions about your farm"

Additional qualitative data were derived from some open-ended questions such as "What is the PRIMARY reason for why you decided to use each of the following management practices? Please select only ONE option. - Other 2 (please describe)", "Please provide UP TO THREE additional reasons for why you have implemented the following management practices". Also, qualitative data were derived from interviewing the contact person in OSN (coordinator) using a semi-structured script which allowed for a more conversational style. This contact is an operational administrator of the network, thus the most suitable person for the interview. The interview was useful in understanding the background and general questions not directly involving network members (see Appendix B). For instance, clarification on why OSN is considered a farmer-led

network when ROI is the administrator and project lead. This method was most suitable for gaining insight on areas the survey could not provide and future goals of the network were discussed.

3.5 Data Analysis

Data collected were analysed based on the identification of network variables as the independent variables which will be used in explaining adoption of BMPs as the dependent variable (Borgatti, Everett, & Johnson, 2013). Out of 40 farmers surveyed, 28 responses were received. After cleaning data and removing repeated responses, 23 respondents were left. Respondents were coded according to their sequence of response alphabetically from A to W. Raw data were separated into different segments based on network questions vs. non-network questions. Likert scale questions were converted on the appropriate scale ranging from 1 to 5. Non-network data were analysed using descriptive statistical tools such as percentages, mean and standard deviation.

3.5.1 Whole network structure

For network data, matrices were plotted on Excel and entered on Ucinet Analytics software (Borgatti, Everett, & Freeman, 2002) and NetDraw in Ucinet was used for visual representation of network structure. It is important to note that network size varied with network question. This variation was due to actors not responding to some questions. Consequently, networks varied and a compilation that summarized the key measures was tabulated. However, the key metrics were not normalised as this was not a comparison per se but a summary of measures.

The focus of analysing interactions in the general interactions or overall network was to understand the structure in terms of size and form, cohesiveness, connectedness and density, and position (centralization). This was analysed using binary data i.e. the presence or absence of interactions with actors and it was undirected (symmetric). This simply helps in finding

connections between nodes without considering the direction of ties (sender or receiver). Network cohesion was determined based on measures of density, average path distance, diameter, component, transitivity and centralization (core vs periphery actors):

3.5.1.1 **Density**

The number of ties present in a network to the number of possible ties or actual ties divided by the number of potential ties in the network. The closer the value is to one, the higher the density in the network. It can also be interpreted as percentage.

3.5.1.2 Connectedness

When there is a path between every pair of nodes. It is the ability for all nodes to receive or send information

3.5.1.3 Reachability

A connected network has all pairs that are reachable (Wasserman & Faust, 1994). This is more of an indirect measure indicated from other measures such as diameter.

3.5.1.4 Diameter

The number of maximum steps required to reach from one node to any other node in the network. It is important because it quantifies the distance between two farthest nodes in a network (Wasserman & Faust, 1994). It also describes reachability.

3.5.1.5 Number of components

A connected network has only one component (Wasserman & Faust, 1994). While a fragmented network has more than one component and its degree of fragmentation is quantified by measuring the number of components. It is also another metric used in describing reachability.

3.5.1.6 Reciprocity

Indicates mutual sharing or exchange of information and other resources in the network. It is useful in building trust.

3.5.1.7 Transitivity

It indicates strength of actor (transitive) relationships in a network i.e. the friends of friends who are also friends. The closer the value is to 1, the stronger the actor relationships.

3.5.1.8 Centralization

Group centralization indicates variability or spread and distribution of nodes in a network (Wasserman & Faust, 1994). The larger the value (i.e. closer to 1), the more likely that a single actor is more central in the network while the other actors are less central. In a network, actors who are less central are in the periphery while actors with considerable centrality are in the core of the network. It can be easily used to compare networks.

3.5.2 Types of network

In addition, based on the network questions, there are five networks based on relations asked about in the survey: frequency of communication, actor perception of communication, farming conversation, nature of communication and external influence. They were analysed based on centrality measures (degree and betweenness). Centrality measures are commonly used to identify key nodes (actors) who influence communications and activity in a network (Díaz-José et al. 2016). A relationship between communication frequency and actor production decision change, and actor satisfaction prior to joining OSN and production decision change were assessed using QAP Correlation and Regression, significance was evaluated at $p < 0.001$.

3.5.3 Individual (actor) node level

While at the individual node level, the focus of analysis was to identify the key nodes (actors) based on position and influence. Considerations of actor position was mainly in terms of prestige i.e. the direction of ties (sender or recipient) and not just the actor being involved using centrality measures of degree, betweenness and closeness.

3.5.3.1 Betweenness centrality

Measures the contribution of each node in minimizing the distance between nodes in the network (Freeman, 1979). The node lying in the geodesic path of many nodes has considerable control over the information these other nodes receive. This node is usually termed a bridge or gatekeeper or mediator. This node(s) exerts interpersonal influence on others in the network.

3.5.3.2 Degree centrality

It indicates the number of ties that a node has (Freeman, 1979). For directed networks, it is expressed as out-degree (d_o) and in-degree (d_i) centrality. The in-degree specifically refers to the prestige of an actor in a network. They are the actors who receive the highest nominations.

3.5.3.3 Closeness centrality

It indicates the distance between a node and other nodes i.e. how close an actor is to all other actors. It is valuable in ease of interaction and the speed of dissemination of information. It is expressed as out-closeness and in-closeness in directed networks.

3.5.4 Qualitative data

For the qualitative data, a deductive codebook was derived (Table 2) based on four out of seven principles of resilience of ecosystems by Biggs et al. (2012). Although all the principles do overlap and clearly drawing boundaries can be difficult, these four principles were however

chosen. This is because the aspect of agroecosystem under consideration is the social and specifically management (i.e. governance related principles). Also, resilience is a complex concept, it may not be directly observable, thus difficult to measure. Surrogates were therefore derived in line with Carpenter et al. (2005) suggestion on using proxies to assess resilience as shown on Table 2. Content analysis (Krippendorff, 1980) was used in identifying themes in line with the subcodes of each surrogate from the responses (survey and interview) accordingly. Interpretations were made where necessary using the subcodes as the guide. Evidence was first rated as "Yes" or "No" representing presence or absence of that principle. Then facts supporting this assessment were presented.

Resilience principles were assessed at two levels: actor and network. Actors were assessed based on, change and adoption of new BMP suggest learning and experimentation, systems thinking and use of multiple BMPs, frequency of contact and individual sector participation. At the network level, participation in sector activities was used in assessment while the other were assessed based on interpretive analysis of actors actions.

The semi-structured interview was conducted to gain more insight on areas not covered in the survey. For instance, why the network is called a farmer-led peer network and getting a general idea of administration of the network. The range of questions include "Why is it called a farmer-led network?", "Can you throw more light on the 1year early adopter program?". Data using both description and interpretation focused strategy (Saldaña, 2013). In the first cycle of coding, after listening to the verbatim audio recording, codes were developed using the interview script as a guide. Then the codes were categorised by consolidating the similar codes and linked to the objectives.

Table 2 Deductive codebook for resilience principles, parent code represents the main principle while subcodes represent indicators of how the principle is applied, description provides details of what to look for and questions are used in the survey to extract evidence of the principle

Parent code	Subcodes/childcodes	Description	Questions
Learning + Experimentation	Change in norms	Changing from normally used practices/methods to BMPs	Since joining the Ontario Soil Network, have you adopted any of the following soil health management practices on your land?
	Trying new BMPs	Adopting new BMPs counts for using new knowledge or trying new practices (e.g. experimenting)	Have you adopted any of the following soil health management practices on your land?
Fostering CAS thinking	Systems thinking	Demonstration of holistic perspectives in managing soils	Since joining the Ontario Soil Network, have you adopted any of the following soil health management practices on your land?
	Multiple practice	Rationale for using more than one soil management practice	Provide up to three reasons for why you have implemented the following management practices
Broaden participation	Sector participation	Involvement in decision making processes in the sector (e.g. town hall meetings, public hearings, etc) could mean participating more broadly.	Are members of the network actively engaged as relevant stakeholders in projects/decision-making of government agencies, other relevant organizations? E.g. public hearings or any government feedback process?
Connectivity	Frequency of contact	Number of times which members communicate	How often do you communicate with this person?
	Communication type	Nature of communication exchange e.g. advice, information	Do you speak with person about farming?

		What is the nature of communication with this person?
Valence	Overview of communication	Are your communications generally positive, negative or neither?

However, there are some codes that did not satisfy the research objectives but were helpful in understanding the network. For example, codes on network formation and why it was formed? A total of five themes eventually derived: dynamics, interactions, broader participation, learning, and sustainability. These themes informed a major part of the discussion.

4.0 RESULTS

In this chapter, the results are organized in terms of two objectives of the study. First, social network analysis was used to highlight the structure of OSN and how this affects its primary function of BMPs adoption. The structure reveals a cohesive network (see Table 3) with considerable potentials to foster adoption of BMPs. Second, using surrogates as proxies for four resilience principles, FNs were assessed if they contribute towards a resilient agricultural system. FNs contribution to resilience of agricultural systems was clearer based on two principles while contribution to the other two principles was not distinct.

4.1 Objective 1: Network Structure and Function of formalised FNs can influence adoption of BMPs.

4.1.1 Descriptive Results

Table 3 Descriptive reslts - Variable definition and descriptive statistics for the general interactions of the network. Network relations were dichotomised to show the general cohesiveness without considering direction of ties. This is useful in understanding adoption of BMPs which is the dependent variable

Variable	Values
Dependent variable**:**	
Adoption of BMPs -	
Adopters	90%
Non-adopters	10%
Independent variables	
Overall Network variables	
Number of nodes	22
Density	0.69
Mean	0.48
Standard deviation	0.50
Avg Distance	1.31
Transitivity	0.75

4.2 Network structure

The network can be described as cohesive and hanging together into a single component without subgroups or fragments. It is quite dense with a 69% actual node connection in comparison to the potential of this network. From the graph (Figure 2) representing undirected and unweighted interactions in the network i.e. a basic presence or absence of interaction, all actors in the network are reachable. The network diameter of 2 indicates that the two furthest nodes can be reached through two steps. The characteristic path distance (Table 3) indicates that one node is between any given pair of nodes in the network. Transitivity value of 0.75 also suggests stronger relationships within the network, i.e. friends of friends are likely friends too.

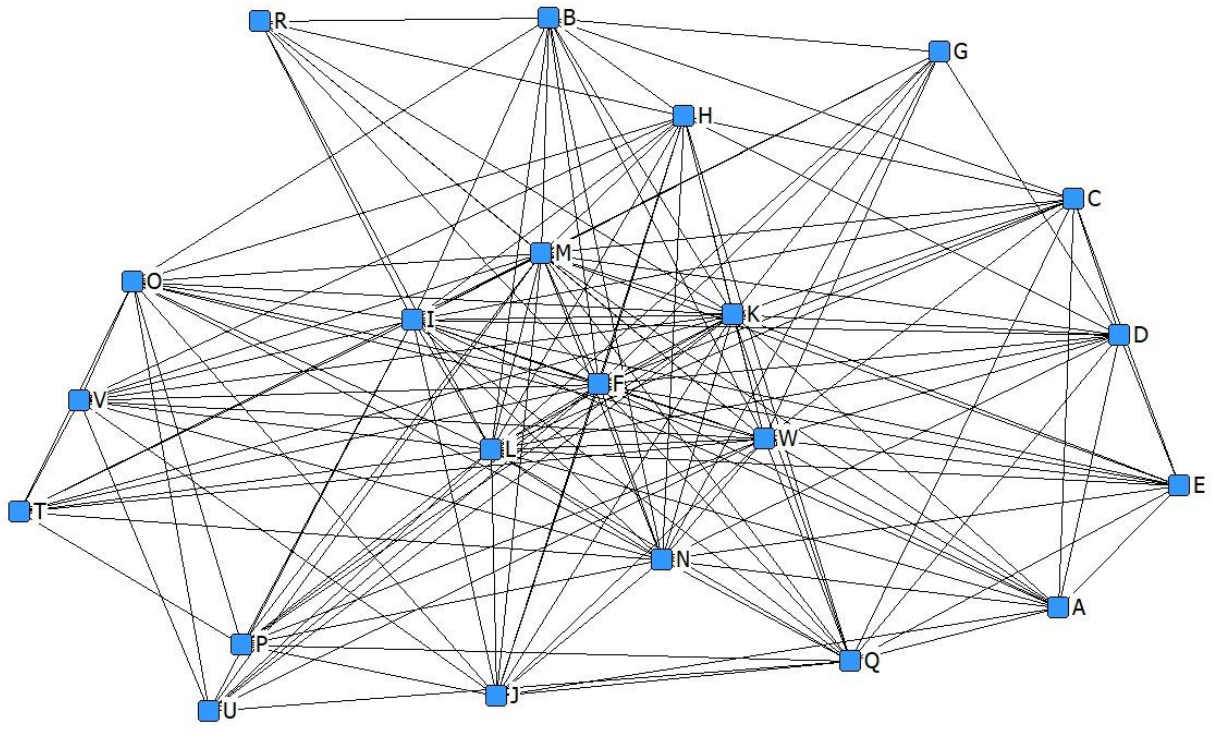

Figure 2. Graph showing undirected and unweighted network interactions

In terms of reciprocity of general communication within the network, reciprocated directed ties (122) is higher than unreciprocated directed ties (99) while arc reciprocity is 0.54. Out of all the directed ties (arc) in the network, 54% are reciprocated. This is highlighted in Figure 3; the green lines indicate reciprocal ties while the pink lines indicate unreciprocated ties. Moreover, higher asymmetric (directed) dyads which is almost double of symmetric dyads is indicative of a presence of hierarchy in the network. In addition, the network has transitivity value of 0.75 indicative of strong relationships between actors.

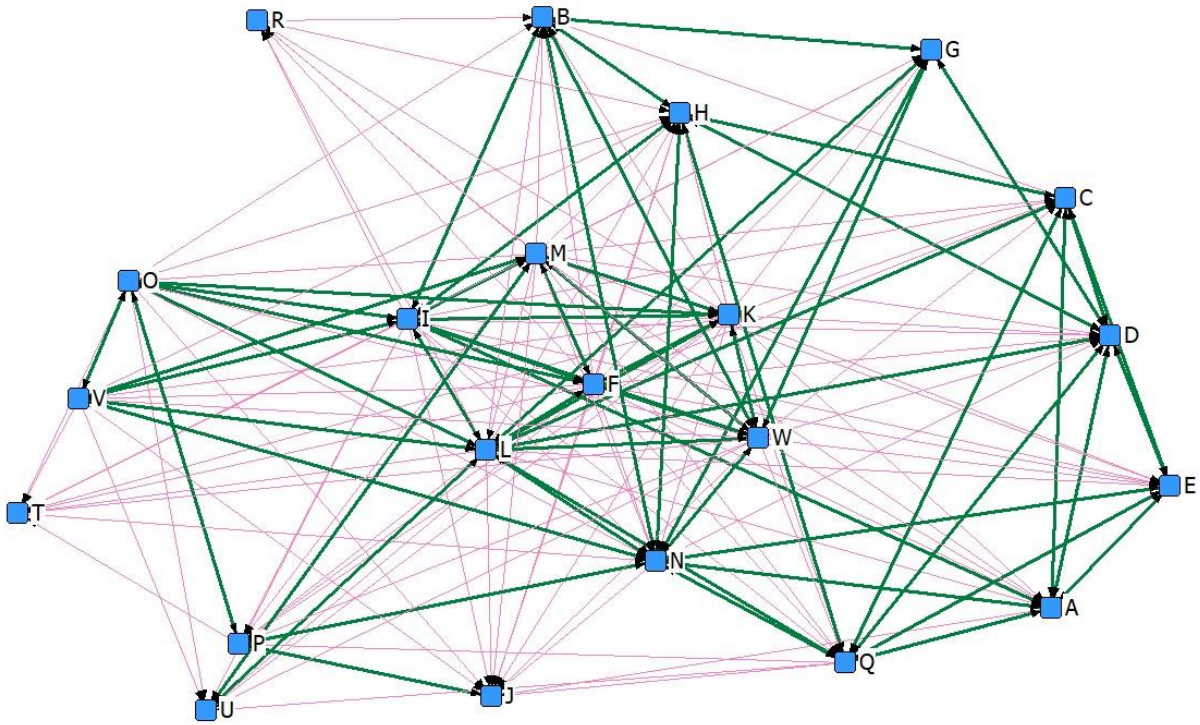

Figure 3 Digraph showing reciprocal ties in green and unreciprocated ties in pink

To further describe the network, different aspects of communication from the survey were considered. The frequency, type of communication (message), perception of actors about their

communication and why they communicate. In highlighting these aspects, positions and roles of actors will also be identified for better understanding of the networks.

4.3 Types of Network

In this section, the different types of network assessed based on relations in the overall network presented.

4.3.1 Communication frequency network

One actor (S) was removed for not responding to survey question (how often do you communicate with actor…?). The network was valued based on frequency of communication between actors. Frequency ranged on a scale of 0 to 5 for "Never", "Less than once a year", "Yearly", "Monthly" and "Weekly" respectively. The mean communication frequency is 1.0 i.e. less than once a year and SD 1.4. In Figure 4, six key actors (L, M, W, I, K & F) are highlighted.

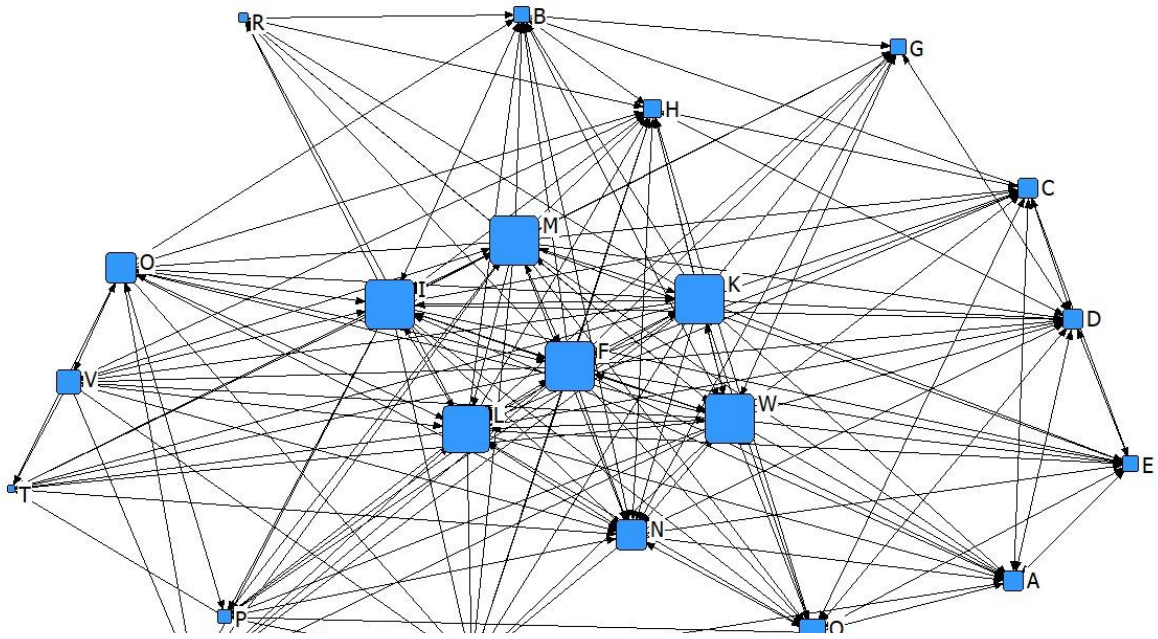

Figure 4 Outdegree centrality for communication frequency network. L communicates with other actors most frequently. This graph also highlights the six key players

However, L has the highest outdegree of 68 whereas in terms of in-degree centrality, actor N has the highest value of 40 and highest betweenness centrality (53).

Closeness centrality indicates the actor with the shortest distance to other actors within the network and how quickly they will interact with them. The actor also doesn't need to rely on other actors to communicate and diffuse information such as BMP adoption. In the communication network, F, I, K, M & W, are the most central for out-closeness (1) while node N is the most central for in-closeness (0.80)

Another perspective to consider in describing structure of the general communication network is its centralization. A, C, D, E, H, I, L, N, Q, are the core actors whereas actors in the periphery are B, F, G, J, K, M, O, P, R, S, T, U, V, W. Fitness correlation of 0.55 indicates strong fit but far from ideal. Five actors in the periphery connected with external organizations while only three core actors connected with external organizations. In terms of connections to individuals, six actors in the periphery connected to at least one individual outside the network whereas five actors from the core connected with at least one individual. Overall, periphery actors are more connected externally than core actors. The actor with the highest number of external connections, S, relates to 5 organizations and 10 individuals.

4.3.2 Actor perception network

To better understand how general communication within the network is viewed by actors, survey question was framed as "Please answer each question for the following farmers based on your experience since joining the... - Are your communications generally positive, negative, or neither (neutral)?". 114 responses from 18 respondents showed that 75% considered their communications with identified actors as positive while 25% were neutral. No respondent considered their interactions within the network as negative. Actor L has the highest proportion

(13%) of interactions considered as positive and an in-degree centrality of (11) while B & M had highest outdegree centrality of 17 each. From a network perspective, the arc reciprocity of 0.51 indicates that 51% of ties (see Figure 5) based on how actors perceive themselves are mutually shared. A visual consideration of how actors perception reveals that five actors (D, Q, A, C, & E) share a strong reciprocity in their local neighbourhood and are clustered to the left side of the digraph. They also form three close triads: D, E,Q E,O,C & C,O,A.

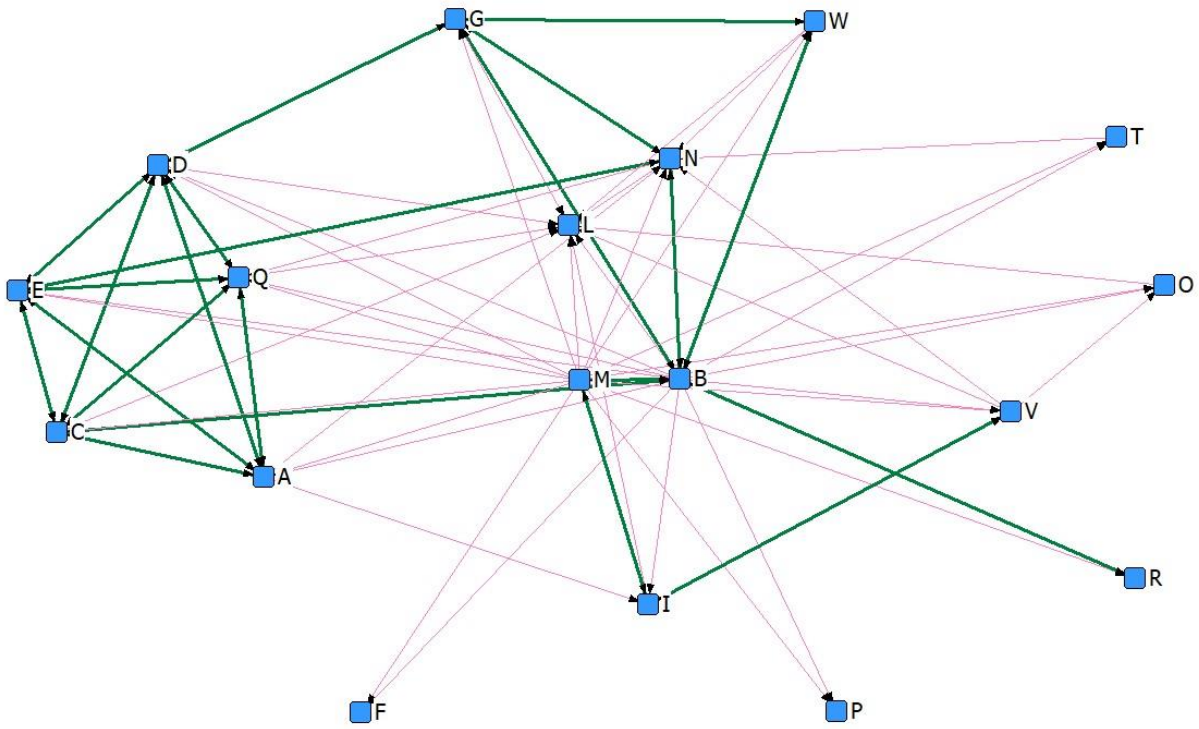

Figure 5 Digraph showing reciprocity of actor perception on communication

4.3.3 Farming conversation network

This network was valued based on how frequent actors conversed about farming. The question was “Do you speak with this person about farming?”. The response was binarized, 0 – “No” and 1 – “Sometimes” and “Yes”. Farming conversation network is highly dispersed with a density value 0.29. Farming conversations with actors is most centralized around H, L & N. These

are the actors with the highest nominations (10) which peers go to converse about farming. Whereas L is the most prominent actor in approaching peers (outdegree centrality) on farming conversations with an outdegree of 21. In terms of betweenness centrality, L has the highest betweenness value (128). Arc reciprocity of 0.61 indicates that 61% of actors mutually shared information on farming (see Figure 6).

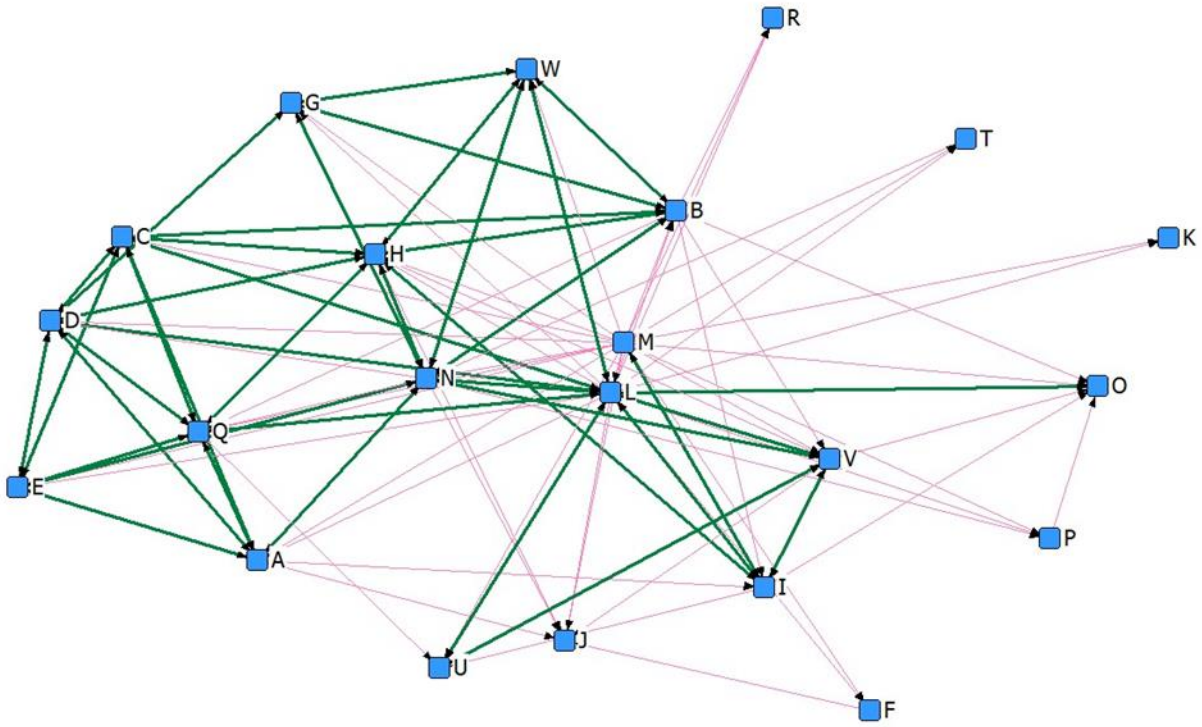

Figure 6 Digraph showing reciprocity in farming conversation network.

4.3.4 Nature of communication

Some actors (n=4) were excluded for not responding to the survey question (What is the nature of your communications with this person?). The nature of communication network was not well connected, and where connected, the density of ties were low. However, out of the total

respondents (n=19) 53% considered their nature of communication as mutually beneficial, 37% either asked for advice or provided advice to other actors while 10% shared no information.

4.3.5 Actors production decision change

An actor's decision to make production system changes was considered in two dimensions. One dimension is making this production changes as a result of fellow actor (internal influence) while the other part is due to external influence (individual and organization). For the internal aspect, actors were asked "Since joining the OSN, have you made a production system change as a result of your communication with this person?". Both actors B & M have the highest in-degree centrality value of 4 whereas actor L has the highest out-degree centrality with a value of 18. This means the B & M were nominated as the actors with the most influence on others in making production decision change whereas with L, values are indicative of actor's production decision change traced to most actors in the network.

For external influence, actors were asked "Since joining the OSN, who from OUTSIDE the OSN has influenced your decisions about your farm?" and "Since joining the OSN, are there any new or different sources you turn to related to soil health - Has this source provided useful advice to you?". The former question represents individual (informal) while the latter represents organization (formal). In both categories, a total of 11 actors responded to the survey questions while 12 responses were removed Actor S had the highest number (33%) of external connections made in the network For external sources (organizations) influence, social media had the highest nomination (20%) while government agency and private consultants had 13% nominations. Individual sources could not be classified as the occupation or their affiliations were not provided.

Also related to production decision change, actor mentorship (Is there a farmer or farmers who you look up to within the OSN? If so, please identify them and provide a short explanation of

why.) result show that H received the highest nominations (Figure 7). Whereas, in terms of influencing production decision change, B received the highest nominations. A QAP correlation indicates a weak positive correlation r = 0.47 (p = 0.01) between mentorship and production decision change.

Furthermore, actors reasons for choice of mentors reveal that trust is being built, presence of cooperation and recognition of others as experts with valuable knowledge to tap from. Others include resourceful – "he knows a lot about a lot of things"; adaptability – "love for learning and willingness to stick his neck and try new things"; experience – "depth of experience"; value – "great to talk with and share ideas", "open communication". A few actors believed that they looked up to everybody because even with their differences, they share similar challenges.

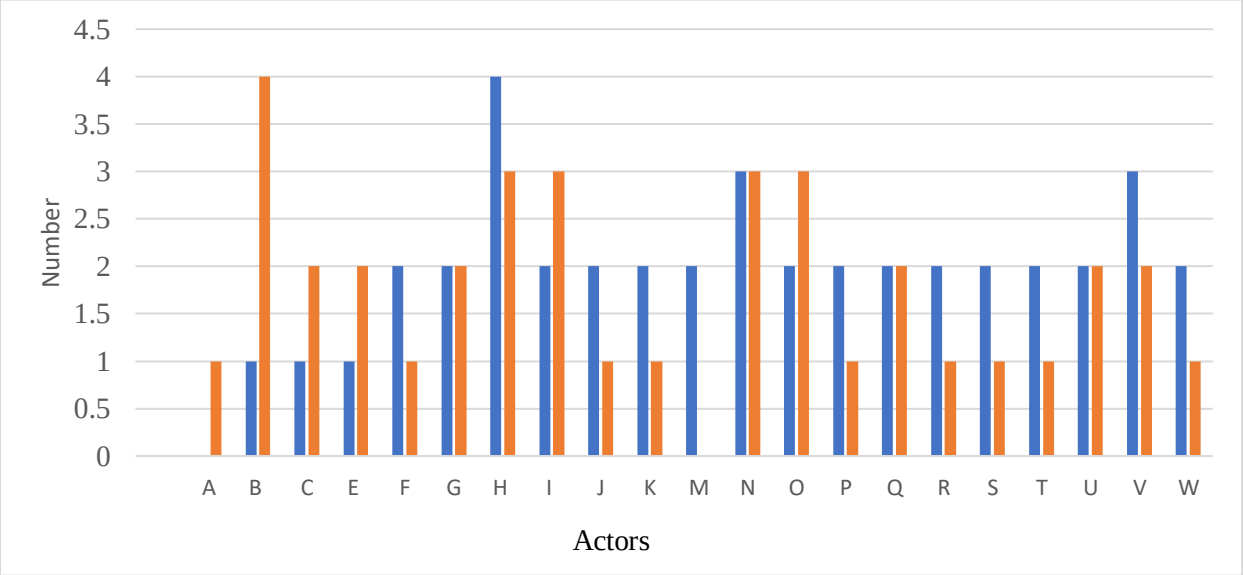

Figure 7 Chart comparing mentorship (orange) vs. influence on production decision change (blue) within the network. H had the highest nominations as one people look up to in the network but in terms of influencing actors to make production decision change, B had the highest nominations

4.4 Summary of Networks

The types of networks based on relations within the OSN are summarised on Table 4 showing the main measures for each of the networks. It is important to state that it was not a comparison per se but simple compilation of key network measures. Hence, the reason for not using normalised values. More actors were active in frequency of communication and farming conversation. The number of links present in frequency of communication, followed by farming conversation whereas motive of communication network is highly dispersed. Degree of centralization indicates that production decision change network (0.86) is most dependent on a few or single central actor(s) followed by farming conversation and perception of communication. Motive of communication is least dependent on central actors.

Table 4 Summary of networks and key network level measures

Type	Total nodes	Density	Degree centralization
Frequency of communication	22	0.49	0.34
Farming conversation	22	0.29	0.66
Perception of communication	18	0.28	0.65
Nature of communication	19	0.05	0.28
Production decision change	19	0.12	0.86

4.5 Summary of Key actors across the networks

The position of actors and their influence varies across the different networks in this study including the type of centrality measure. Table 5 summarizes the most influential actors based on three centrality measures: degree, betweenness and closeness. Actor L communicates most frequently with other actors and in conversations around farming. L also indicates to have been influenced the most from these interactions to make production system change since actor

nominates almost actors as influencing production decision change. L is also a bridge on production decision change and can most directly connect to different parts of the network. L is the most popular in terms of positive communication. Actor N is the most popular in terms of the frequency which others contact N. This actor also has the shortest distance in reaching others and others will N quickest again because of having the shortest distance for farming conversation. N is also one of the two popular actors others reach out to on farming conversation. In terms of disseminating information on farming conversation, actor B has the shortest distance. Actor B also nominated the highest number of actors as sharing positive communication. B is the most popular actor for giving or receiving advice and one of the two highest influencers for production decision change. These three actors have the highest mode of centrality measures across all networks, other key actors are illustrated on the Table 5.

Table 5 Summary of Key actors across the networks and their centrality values of degree, betweenness and closeness. These networks are asymmetric, hence the in-and-out sub categories for degree and closeness centrality

Type	**Indegree centrality**	**Outdegree centrality**	**Betweenness centrality**	**In-closeness centrality**	**Out-closeness centrality**
Frequency of communication	N (40)	L (68)	N (53)	F, I, K, M, W (1)	N (0.8)
Farming conversation	H, L, N (10)	L (21)	L (128)	N (0.50)	B, M (1)
Perception of communication	L (11)	B, M (17)	B (90)	B & M (1)	L (0.63)
Nature of communication	H (5)	B, C (4)	H (5)	H (0.35)	C (0.32)
Production decision change	B, M (4)	L (18)	L (89)	B, O (0.22)	U (0.5)

4.6 Adoption of BMPs

A total of 20 respondents show that 90% of actors adopted at least one BMP since joining the network while 10% did not adopt any BMP. Further consideration shows that the actor (D) with highest number of BMP adopted (Figure 8.) is not among the key central players across all networks (Table 5). But in terms of overall network centralization, D is among the core actors. Secondly, out of the four actors with the second highest number of BMPs, M has highest outdegree centrality (21) while the other three (A, E & G) had higher indegree centrality 11, 11 & 9 respectively. In addition, out of the four actors with highest in-degree centrality, three (L, B, M) adopted BMPs while N and T did not adopt any BMP because they were already using all listed BMPs.

Recognizing that there are various reasons why a farmer may decide to adopt a BMP, actors were given a bank of reasons to choose (Figure 9.). The most popular reason (primary) was that "it was better for my farm".

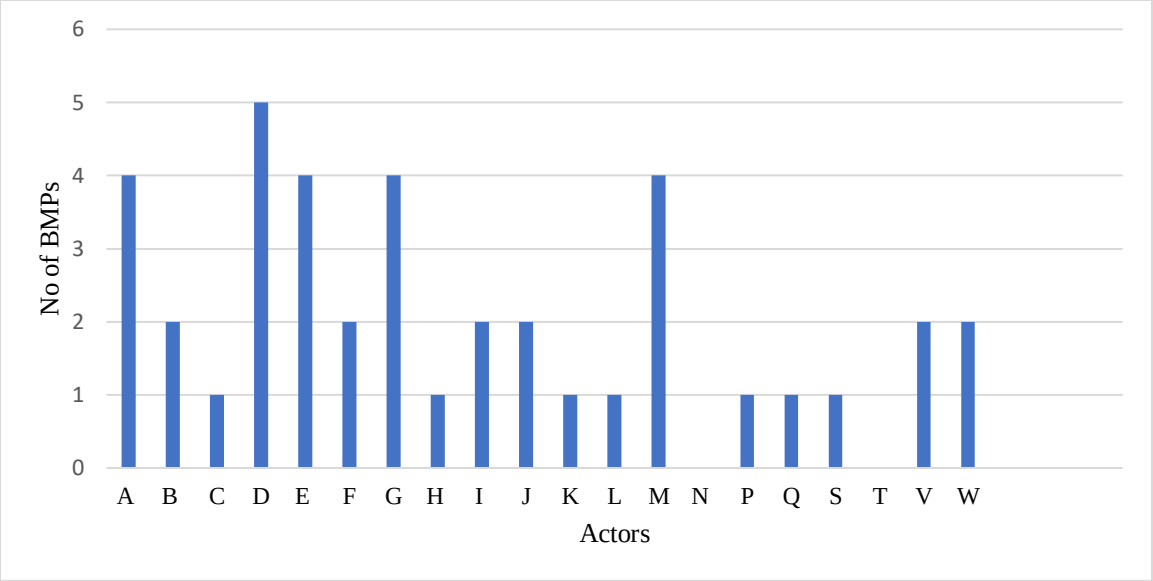

Figure 8 No of BMPs adopted by actors since joining OSN

Actor L adopted one BMP even when being one of the most active in most networks with roles as influencer and bridge in farming conversation network. The additional reason provided is that it was based on need and urgency due to the prevalent risk of wind in the area which the actor's farm is located while for cover crops, the actor expressed uncertainty on how best to apply the most suitable cover crop for grain crops.

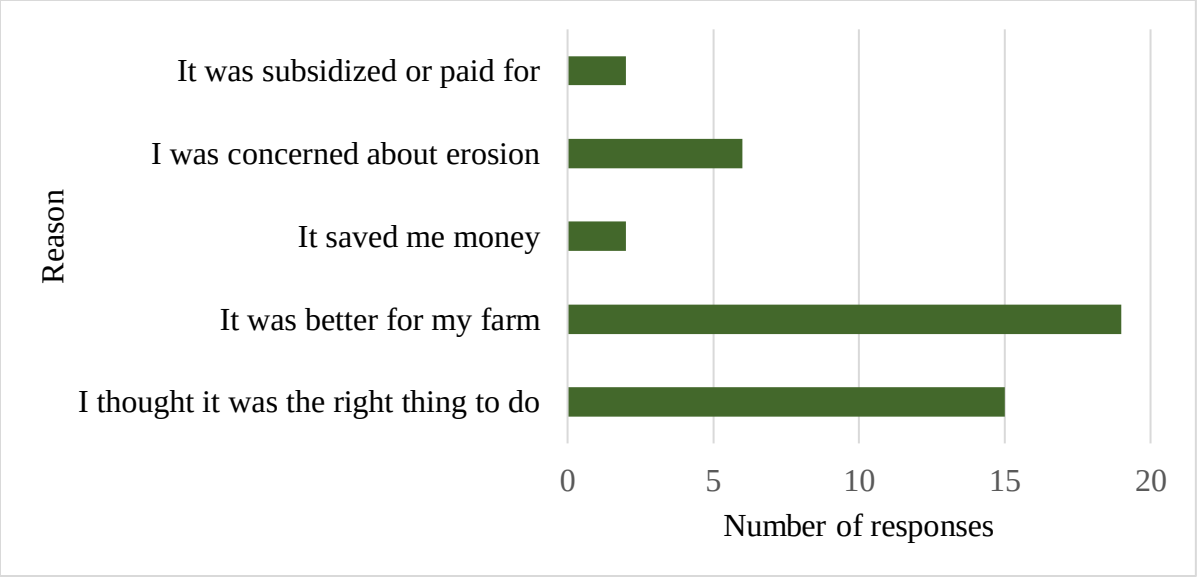

Figure 9 Actor primary reason for BMPs adopted.

4.7 Comparison between Satisfaction prior to OSN and Adopted BMPs

Satisfaction with prior soil management practices was rated on a Likert scale ranging from very unhappy to very happy i.e. 1 to 5 respectively. Out of 23 actors surveyed, 20 were either very happy or happy while none was unhappy or very unhappy. The mean for satisfaction is 4.2 (SD =0.66). This means that most actors were happy with soil management practices prior to joining OSN. QAP correlation for satisfaction prior to OSN and number of BMPs adopted value $r = 0.05$ ($p < 0.01$). This is a rather weak positive relationship between the two variables. It therefore means that an actor who is satisfied with soil management practices prior to joining OSN will not necessarily adopt BMPs.

4.8 Comparison between frequency of communication vs. production decision change

The digraph (Figure 10) compares communications and production decision change as a result of interacting with other actors in the network. Actor G has the highest frequency

communicating with N i.e. communication on a weekly basis but this did not influence production decision change. Similarly, actor L as illustrated in earlier sections (farming and nature of conversation) is the most central actor with highest out-degree values (21 & 18 respectively). L communicates with majority of actors in the network on average between weekly and monthly but has low influence on actors in their production decision change. Rather, actors B & M with frequency of communication out-degree of 16 and 43 respectively have the highest degree of centrality for production decision change (see Figure 10). QAP correlation coefficient r =0.49 ($p < 0.001$) suggest that frequency of communication moderately affected production decision change. This means that those who communicate with others more often tend to influence production decisions more often. Similarly, QAP linear regression indicates r = 0.49 ($p < 0.01$), indicating that more frequent communications will likely lead to positively influencing adoption of BMPs.

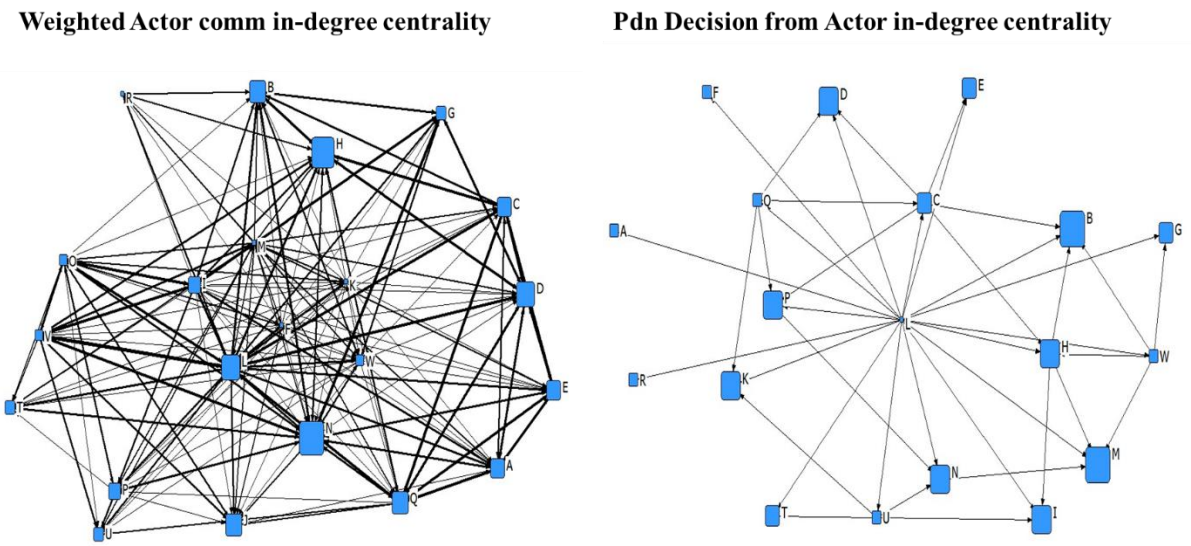

Figure 10 Graphs comparing frequency of actor communication and production decision change. Node attribute for both graphs is based on in-degree centrality. Frequency of actor communication (left) relations shown are based on tie-strength, the thicker the black lines the more frequent the communication.

4.9 Objective 2: Principles of Resilience

Surrogates were derived as proxies for the four principles of resilience of Biggs et al. (2012) in compiling a deductive codebookto evaluate if FNs structure can contribute to agricultural resilience both at an individual and network level. Evidence from survey (Table 6) and semi-structured interview were coded using the codebook as a guide.

Table 6 Deductive Codebook highlighting evidence gathered from the survey and interview for FNs contribution to agricultural system resilience. Surrogates are the proxies derived from each principle while evidence from study are themes related to the surrogates from survey and semi-structured interview

Principle	Surrogate	Evidence from the study
Foster Complex Adaptive system thinking	Use of integrated/holistic/multiple approach (systems thinking) in soil/crop management.	No; About 50% of respondents' rationale for adopting new BMP included at least ecological or economic or both. Most of those that did not adopt any new BMP stated that they were already using all the listed options on their farms. But the rationale presented are not strong to satisfy CAS thinking principle.
	Demonstrate understanding of management of multiple ecosystem services	Yes; 57% of respondents stated more than one ecosystem service provided by BMP adopted was contributing to their farm system. Examples: "We have cattle, so the cover crop is used for grazing as well as healing the soil. We make compost because we have cattle manure and it is better for the soil if the manure is composted before spreading and we do some no-till work again because it is less damaging to the soil biology" "increase the organic matter in my soil. increase soil microbiology. increase the water holding capacity of my soils"
Encourage learning and experimentation	Learning is in the form of modifying existing or acquiring new knowledge, behaviours, skills, values or preferences	Yes, 61% adopted more than 1 BMP while 78% adopted at least 1 BMP and 21.74% did not adopt any BMP

Broaden participation	Active engagement/feedback into of members in sector wide decision-making/lobbying, collective action.	Yes, some members are involved on individual capacity prior to OSN. "Individual involvement with NGOs and government (OMAFRA)"; (source - interview) 87% of actors are involved in farm associations (source– survey responses)
	Involvement as an organization/administration in decision making processes e.g. town hall meetings, etc.	"organizational level involvement is not extensive, low level involvement with govt decision-making with OMAFRA in strategy work e.g. Ontario Soil Strategy" (source – interview)
Manage Connectivity	Frequency of interactions (meetings, chats, discussions, etc). Form of interaction: call, email, in-person.	Yes. "No fixed number; members meet more informally, mean value for annual meeting attendance is 4.4 (SD=3.9); online meetings and webinars have been introduced with COVID-19 (source – interview) attendance not mandatory" Social network analysis of OSN reveals a highly connected group with no subgroups (density -0.69; transitivity – 075)
	Quality of farmer interactions within the immediate network Type/nature of communication	Yes, 75% of interactions considered positive while 25% was neutral. No negative interactions.
	Quality of farmer external interactions	Yes, exchange of advice was considerably high: mutual advice – 53%, one-way advice (give or take) – 37%, no exchange – 10% No – weak external interaction, about 50% interacted with at least an individual or organization
	Certain actors serving as connectors (bridge) to other	No actor is externally connected in a way to bring new ideas. However, one actor (S) has been identified as a potential bridge

	landscapes, bringing new ideas and perspectives.	with strong external connections: 5 – organizations and 10 - individuals

5.0 DISCUSSION

Objective 1: Network Structure and Function

One of the motivating questions for this work is how FNs structure can affect adoption of soil BMPs. To provide an understanding on this, a structuralist theory approach (Marin & Wellman, 2011), is used to elucidate the pattern of relations in a social network and how it can influence diffusion as its function.

5.1 Nature of Ontario Soil Network (OSN)

It is indeed true that not all social networks are created equal (Newman & Dale, 2005), different structures have different implications on governance of socioecological systems (Matous & Todo, 2015). In classifying the OSN, the line between formal and informal appears blurred. OSN has a defined purpose and structure which is characteristic of a formal network (Monge & Contractor, 2003). But this status is seasonal, contingent on the availability of funds. Then the network reverts to informal status where its activities are not structured. The informal characteristic of this network is affirmed by the non-mandatory nature of meetings and the lack of determined number of meetings annually. This description fits the lack of organizational prompting of informal networks described by Pape & Prokopy, (2017). It also supports Matous & Todo, (2015) view on the structure of networks being observed at a given time is temporary depending on evolution which is dynamic, changing according to constraints and preferences. In view of this circumstantial fluctuations, OSN can be considered a quasi-formal FNs.

Another way to describe this network is to consider it as a practice-driven diffusion or extension network. A similar approach has been used by the European Union funded farmer-led multi-actor network, Hennovation (between 2015 – 2017) established to encourage practice-driven

innovation for laying hen sector (Main & Van Dijk, 2017). OSN is also publicly funded with ROI acting as a partner to assist in accessing funds. However, there are plans to incorporate the OSN in year 2020. It is uncear how this will affect funding. Nonetheless, the important thing is choosing the most suitable model given the unique circumstance in order to sustain FNs.

5.2 Network structure: general interaction

The network is well connected and cohesive based on its relatively dense nature, short path distance i.e. just one node between any given pair, high transitivity, absence of fragments and its existence as one component. Hence, actors are easily reachable (Wasserman & Faust, 1994). This is a great feature for spread of information and resources within the network. The size of the network may be a contributing factor to its cohesiveness since there is a higher chance of nodes interacting in a small size network. The cohesiveness in OSN may be indicative of actors who are focused on achieving the objective of the network.

However, high cohesiveness can be detrimental to heterogeneity of actors discouraging new entrants. Sandström & Carlsson, (2008) suggest that highly dense ties can be detrimental to innovation and heterogeneity. But this feature was not part of the survey apart from knowing that they are all farmers, so not much comments can be given in this regard. Absence of bridging ties is indicative of a network with high bonding ties. Presence of many bonding ties does create feeling of trust among actors in a network Coleman (1990) in (Bodin et al. 2006). Also, homogeneity can be obtainable when actors have the same function which in this case is diffusion of BMPs. Homogeneity is not always bad. It is useful in helping expand networks. For instance, it was discovered that farmers with high density and homogenous contacts grew their networks faster than those with less dense networks and diverse contacts (Woodet al. 2014). This was helpful in

knowledge exchange between some pastoral farmers as an alternative non-linear pattern of agricultural extension.

In addition, high reciprocity in the network indicates a considerable exchange of information and ideas within the network. This was observed in most networks. This positively impacts functioning of the network. Actors mutually hold one another in high regards and perhaps this influenced their conversations like farming conversations which was highly reciprocal. This is good for diffusion and adoption of BMPs and it can be helpful in collective actions too. This will generally strengthen the network and building trust will be easier (Matous, 2015). Lack of reciprocity has been found to be detrimental to conservation practices both at household (individual) and collective (FNs) levels (Matous, 2015). Also related is with high reciprocity, social memory can be accessed easily particularly as they are also easily reachable in the network.Sharing experiences is particularly relevant during periods of change and uncertainty. This is where the retention of farmers in the leadership program is paramount to contribute to this function.

In terms of network centralization, the OSN has actors arranged into core and periphery. Periphery actors in OSN had more external connections than core actors. Whereas, core actors are usually more influential at reaching outside the network for resources (Bodin & Crona, 2009), and tend to connect closely with actors within the centre (Isaac, Erickson, Quashie-Sam, & Timmer, 2007). Peripheral actors can only get information within the network from the core since that is where they are directly connected. This feature of one center quickens diffusion than having several subgroups.

For instance, core actors in advice networks of three agroforestry villages in Ghana acted as the bridge for information acquisition and dissemination from external sources (Isaac et al.

2007). However, periphery actors rarely are connected to external sources. In addition, one might wonder how actors are delineated into core and periphery positions. Baksy (1999) in Isaac et al. (2007) suggest from previous studies that core actors are usually purposefully selected based on some attributes that encourage actors to occupy central position. But this may not be the case with OSN since participation in the yearly program is open to all farmers. However, some form of reference is required to attest to farmer's pro-environmental practices. It therefore appears that core actors evolved independently of any purposeful selection.

5.3 Communications

In social networks, communication is a crucial component on how interactions occur. The average frequency of communication among actors in OSN was less than once a year. For more meaningful impact, communication must be more frequent. Pape & Prokopy, (2017) recommend more frequent meetings for social networks to be more effective. Admittedly, meetings may not be the only avenue to communicate but it underscores the importance of interactions. It is easier to build trust with more communication. One actor justification for identifying a peer as a mentor due to having open communication. Also, it creates a channel to share experiences, innovations and potentially collaborate. This is how learning occurs. An appropriate knowledge applied on farms will be to the benefit of a wider society. This can be termed social learning. It is a useful tool in aiding diffusion and adoption (Pratiwi & Suzuki, 2017). However, it is important to note that more frequent communication does not guarantee change, it increases the chances of accessing information and valuing it (Gailhard, Bavorová, & Pirscher, 2015). This has been seen in this study. The actors that communicated most frequently in the network were not the most influential. This will be discussed extensively in the following sections. The key thing to consider is that the quality of communications is as important amongst other factors.

The quality of communication can be explained by content (what is communicated), motive (why is the conversation even going on?). For this study, the quality of communication (positive, neutral, or negative), was mostly positive. This suggests that interactions in the network were contributing to, rather than detracting from, building trust (Dakos, Quinlan, Baggio, 2015). One actor (L) was identified as the most prominent positive communicator and as a 'gatekeeper' connecting other actors in conversations focused specifically on farming. This is a crucial role in introducing new ideas or championing a cause or just circulating information to all parts of the network. This is important if government agencies and private companies (input, service supply) wishes to introduce an innovation. L can be approached as a first contact for this network to connect to other actors.

Furthermore, regarding what kind of communication was ongoing, in the farming conversation network, one actor (L) has prospects as the bridging tie since most nodes in the network need to pass through it to reach other nodes. It is however unclear the strength of this tie. If Granovetter (1973) in (Borgatti & Lopez-Kidwell, 2011) strength of weak ties (SWT) theory is to be considered, then the network may be better off if L has a weak tie otherwise it is likely not going to offer novel ideas and information. Also, Burt's 1990 structural holes theory of social capital argues that instead of a well-connected and one component network, it is better to have a network with structural holes and a few weak ties. Because flow of information within the network will not be redundant, there is room for some novelty with actors connected to one another in subgroups. Redundancy is prevalent with high connectivity; information circulating is pretty much the same and it becomes redundant. This can discourage participation and reduce other benefits. These two views highlight the role that actor L as a gatekeeper can potentially play in influencing flow of information within the farming conversation network. But this actor is not very active with

external interactions. L indicates connection to only one external individual and three organizations.

The quality of communication can also be affected by the motive. Findings indicated that more than 60% of OSN actors either expected to give or receive advice or both. Expecting to give advice or receive advice or both can encourage participation because it is more active. Farmers participation in organizations, clubs and committees can influence knowledge diffusion (Ramirez, 2013). There must be more ways of engaging farmers in OSN. Perhaps make the network more multi-actor focused to stimulate expectations and participation. In general, frequency of communication and farming conversation networks had dense ties indicating that actors were more engaged in these networks than motive of communication.

5.4 External influence vs internal influence on Actors production decision change

In this study, actor decision to change production systems is related to BMP adoption. The assumption is since this question was framed in the context of BMP adoption, then farmers probably responded with this mind. Although decision to change production system does not mean it is BMP adoption, but BMP adoption is a form of change in production decision. For example, changing tillage practices to a no-till or conservation agriculture is a production system change. it is important to note this because reference will be made to production decision change and BMP adoption sometimes interchangeably.

From the point of view of diffusion, Díaz-José, Rendón-Medel, Govaerts, Aguilar-Ávila, & Muñoz-Rodriguez, (2016) pointed out three features of internal influence on diffusion but two apply in this instance. Prestige of actor i.e. the person most identified by peers as someone to turn to for advice or mentor, and Granovetter (1973) role of weak ties i.e. the gatekeeper who is likely to introduce new information into the network. However, prestige may not always result in

influence. The most prestigious actor (H) or mentor in OSN was not the most prestigious for production decision change, rather, it was actor B. This is indeed interesting because it means that regarding one as a mentor may not be enough to influence decision making on production change. Moreover, mentorship was not a popular consideration in the network. Perhaps, actors did not recognize it as an important element in the network. A factor with mentorship is time. It takes time to build relationships to the extent of mentorship. So, perhaps the short duration of one-year leadership program in OSN could explain unpopularity of the survey question.

Another reason for which actors did not consider fellow actors as mentors may be that the farmers are about the same age bracket or it may be that years of experience between actors is at par. To the researcher's knowledge, there is no literature commenting on age and mentorship in social network. But in terms of experience, findings by Skaalsveen, Ingram, & Urquhart, (2020) highlight the influence of experiential knowledge for no-till farmer network. This also supports findings that actor N is the most prestigous in freqency of ccommunication but did not adopt any BMP because all the listed BMPs were already being used by N. This is a form of an edge over other actors and perhaps that is the reason for being the most prestigous. So, the general perception inferred is that they are all experts in their own rights. Mentorship is common when there is clear edge in knowledge or experience between people.

External influence on production decision change was not widespread. This claim is however made with caution since response was from only about half of the actors (n=11). Nonetheless, a few actors clearly are connected to external sources. For external sources which are individuals, no comments can be made on the kinds of person (e.g. if they were mostly farmers or non-farmers) since this information was not provided. Actor S is a potential link to both individual sources and organizations external to the network but inactive with internal interactions. This can

be a good thing since the actor is unlikely burdened with keeping up with too many connections in and outside the network. This phenomenon is termed "excess community" (Woolcock, 1998 in Matous, 2015). In addition, a recent study has shown that an actor with fewer contacts but on a bridging position to main channels of information including external sources is likely going to be engaged in progressive practices than actors perceived to be influential (Zhang, Matous, & Tan, 2020). Therefore, though S has less contacts in the network but if the actor occupies a bridging position to these external sources, then there is prospects of applying BMPs.

For external sources (organizations), it ranged from government source to social media (twitter) amongst other types. Twitter is the most popular medium to access information on BMPs and indeed the most influential for change in production system. But the specific sources on this platform is unknown. This finding highlights the potential of social media as a veritable source of information and awareness on BMP adoption without barriers of location and time (Liu et al. 2018). The authors however expressed some reservations on the quality of information and their review indicated no record of study in this area. A lack of study in this area may partly be due to a confined way of constructing surveys. For example, Pape & Prokopy, (2017) study provided respondents with a list of external sources of information whereas in this study, an open-ended approach was used. Hence, the reason for having varied external sources.

By way of observation, it is interesting that no specific mention was made of extension agent under external sources. Or perhaps their interactions with these sources was via a representative which could pass for an extension agent? Šūmane et al. (2018) suggested that extension agents are sometimes mistrusted, hence some agricultural development projects are faster through informal networks Similarly, Pape & Prokopy, (2017) found that extension agent was the main source of external information for non-network farmers while network farmers

interacted most with crop consultants. An important point to note is that connection to external sources is not always a guarantee that it is beneficial in terms of social learning and improving pro-environmental behaviours, or that ideas will be accepted in the network (Matous, 2015). It basically increases the chances of accessing more information.

5.5 Comparison between frequency of communication vs. production decision change

There is a moderate correlation between frequency of communication and production decision change. But the actors (B,M) with highest degree centrality for production change do not have highest degree centrality for frequency of communication. Presence of links and frequency of links do not convey the same level of importance (Maertens & Barrett, 2013), it depends on the context. Frequency is more about intensity of links and what flows through it. Inferring casual effects on behaviour from interactions is difficult. This can be explained as adoption behaviour being quite complex. Frequency of communication is influenced by the quality of interactions. What controls quality are diversity of the communication network i.e. actor characteristics, how well the actors interact (valency can provide a hint) and the connectedness or density of the network (Gailhard, Bavorová, & Pirscher, 2015). In this case study, the network is quite dense, actors have a relatively positive outlook towards one another. Frequency of communication is not the sole determinant, but it increases chances of accessing relevant information which might result in adoption. For example, organic farmers adopted agri-environmental measures mainly because of frequency of their interpersonal communication (Gailhard et al. 2015). Also, it was established that adoption was more likely if the early adopters were young and well educated. Level of education and age were not attributes considered in this study.

The quasi-formal nature of this network impacts two kinds of diffusion. Diffusion of BMPs via introduction to other farmers which is the primary objective of the network and diffusion via social interaction among members of the network (Young, 2009). The former perspective is beyond the scope of this study, but it can be assumed to occur since these farmers committed to using four methods of reaching other peers e.g. field days. Diffusion via social interaction occurs with interpersonal interactions between farmer to farmer sharing experiences and knowledge on issues common or of interest to them. In the process, ideas and information are exchanged even without noticing or intended. This is more related to this study. So far, it can be deduced from number of BMPs adopted that some level of social interaction adoption has occurred even though the degree is not clear. Keeping this side by side with about 70% actor's satisfaction with past soil management practices prior to OSN, 90% adopted BMPs. It therefore follows that adoption occurred as a result of interacting with other farmers in the network Nevertheless, the BMP adoption in OSN is encouraging going by the adoption figures.

5.6 Objective 2: FNs contributing to the general resilience of agricultural system

Four of the seven principles of resilience proposed by Biggs et al. (2012) were used to examine if FNs can contribute to a resilient agriculture. Surrogates used in assessing network structure of FNs were derived from contextual interpretation of the relevant principles in line with (Carpenter et al. 2005) suggestion for application of surrogates. Findings indicate that FNs can contribute to resilience regarding managing connectivity, encouraging learning and experimentation while broadening participation was in partially evident. Fostering CAS thinking was not evidently supported by FNs. It is important to stress that this analysis recognizes the complexity of resilience and drawing boundaries entails making analytical sacrifice (Bergström &

Dekker, 2014). The focus is on the individual farmer (micro) and network (meso) scales. Also worthy of note is that farmer actions do not guarantee an emergence of the resilience of the whole agricultural system, but its relations and interactions does influence resilience outcome of the whole system. Put differently, micro behaviour of the system affects the emergence of meso and macro behaviours and it is not a straight forward addition, nor a direct control (ibid).

First, connectivity describes the quantity and quality of connections between elements of a system (Cabel & Oelofse, 2012). Although there are no fixed number of meetings, surrogates point to fair level of interactions e.g. an average of 4 meetings annually. Social network analysis revealed considerable level of connectivity in OSN. Also, majority rated interactions as positive, indicating good quality interactions. Since connectivity depends on the structure and strength of networks, then resources (in this case, information) can flow through easily in a densely connected network. This can enhance improvement in soil management through diffusion of BMPs. A secondary effect observed within the network is an unintended adoption of BMPs by actors when the primary aim of the network is diffusion to non-network members.

Furthermore, connectivity conveys resilience to supply ecosystem services (such as soil). Social networks if consolidated can reduce social vulnerability and increase agroecosystem resilience particularly at local and regional scales (Altieri et al. 2015). On the positive side, closely linked and dense networks within communities help to enforce norms and governance of common resources (Dietz, Ostrom, & Stern, 2003). Since the connectivity in OSN is relatively dense, it can help in enforcing a growing norm to farm responsibly and environmental stewardship amongst farmers (Liu et al. 2018). Also, OSN can contribute in better governance of common resources e.g. soil and water through upscaling of BMP adoption. This will contribute to reducing challenges with water quality and use e.g. non-point source pollution of surface and ground water.

In addition, there is value in expanding connectivity to include sources outside the network to be effective in accessing new ideas (Biggs et al. 2012). Within the OSN, a few actors have shown prospects in connecting the network to external groups and this should be encouraged. Varying kinds of ties aids quality of connectivity which in turn facilitates sink-source dynamics that is crucial for recovery and constraint as a barrier to spread of disturbance (Dakos et al. 2015). A study of marine systems showed that actors who are sources of valuable information and other resources can act as barriers proactively preventing sink-actors from impending disturbance. Also at the collective level, Matous, (2015) demonstrated the need not just for external connections but for it to be reciprocal to facilitate adoption of pro-environmental measures. OSN external connectors will need to strive for reciprocal interactions with these external sources to facilitate diffusion and adoption of BMPs.

Overall, connectivity enhances governance opportunities (Dakos et al. 2015). Information shared and trust built from interactions and reciprocity required for collective action (in this case diffusion) puts a farmer on a better stead for effective soil management. From a network perspective, actor position and influence affects governance opportunities. Based on centrality of actors, OSN has two groups: core and periphery actors. The way periphery (specialist nodes) interact with core (generalist nodes) describes nestedness of the network (Dakos et al. 2015). Nestedness determines flow and speed of information and resources in the network. And the capacity of the overall system to adapt to shocks i.e. resilience (Meuwissen, Feindt, Spiegel, et al., 2019).

However, the negative side of high connectivity is that it encourages homogeneity which can be a threat to collective action and resilience. Although the sort of questions in the survey did not directly address heterogeneity, some features of OSN suggest a somewhat homogenous group.

For instance, in terms of occupation, they are all farmers and most of them were satisfied with their soil management practices prior to joining the OSN. The danger with strong actor connectivity is that it can lead to synchrony in negative environmental behaviours which results in holding on strongly to unsustainable practices (Bodin & Prell 2011). Since agricultural systems and the operating context are unpredictable, homogeneity can be counterproductive to resilience. It discourages in flow of new ideas and opportunity to innovate as things evolve. Put differently, high connectivity can be bad for social learning, reducing the ability for experimentation leading to redundancy in the network and system at large. Except functional redundancy, other form of redundancy is a threat to resilience (Dakos et al. 2015). Rather diversity is necessary for a network to be effective enough to support resilience. With redundancy, modularity is low, and stability of the system is also low. Diversity reinforces stability to the point where resistance and recovery are fostered against shocks. But this may not be a problem with the OSN since majority adopted at least one BMP which suggest that actors are open to new ideas even with their prior level of satisfaction with soil management practices.

Learning and experimentation as a principle of resilience was demonstrated by adopting new BMPs and that constitutes acquiring new knowledge or a modification of existing knowledge. Majority of actors learnt new soil management practices even when they indicated that they were satisfied with past practices before joining OSN. This shows that they are trying out new knowledge and even experimenting new practices as they host field days on their farms for other farmers. Learning within the network fits more into social learning which is an outcome of interactions with other actors spread to their community. Intentional learning element is perhaps negligible (Cundill et al. 2015). Learning can be planned or unplanned. Both patterns seem to occur in OSN. Planned learning occurs through dissemination and diffusion methods, Young,

(2009) describes this learning as social learning because others see empirical evidence of BMPs from early adopters. This applies more to farmers who are close to demonstrations fields of the early adopters. With unplanned learning, it as an outcome of interacting with members in the network. Moreover, learning is most likely to occur in the process of experimenting and demonstration from imitation (Šūmane et al.. 2018). But there is also a possibility of the demonstrator to learn in the process particularly when brainstorming ways of illustration. So, learning becomes two-way and creates opportunities to adapt to new situations.

To encourage learning equips farmers with relevant knowledge to take the right decisions and this affects resilience demonstrated in the decision-making process as well as governance process (Cundill et al. 2015). This is so important keeping in mind that the complexity of agricultural systems presents the farmer several production pathways (Gardner, 2019). Hence the need for farmers to learn and continuously. Learning and implementation occurs at individual level, but the impact reverberates up to the system level. Resilience of ecosystem services provided by the soil (e.g. fertility and productivity) is affected when farmers take decisions around management. For instance, a farmer decision to use cover crops in the winter can make all the difference in enhancing resilience of the soil to extreme freezing temperatures. This will fall under adaptive management, one of the three approaches to encourage learning for SES. In addition, it is notable that resilience of SES hinges on its social learning capacity (Davoudi et al. 2013). To ensure that learning is effective, OSN and the early adopters will have to incorporate monitoring mechanisms, encourage more diverse participation and increase provision of financial and human resources.

To assess fostering of CAS thinking, consideration of systems thinking was primary. Only about half of the actors used methods that marginally supported this principle and mostly unaware.

It is understandable because CAS is a complicated concept. More than half of the actors indicated awareness of the benefits of BMPs adopted. And about the same proportion showed that they used more than one soil management practices simultaneously. Integrated soil management is consistent with CAS thinking which emphasizes holistic not reductionist approach to management (Bohensky, Evans, Anderies, Biggs, & Fabricius, 2015). It also means a recognition of agricultural systems as interconnected; change as non-linear and inherent uncertainty and surprise. Chapman et al. (2017), describes CAS in agricultural context as multi-causality, non-linearity, teleconnection, fits and spurts pattern of regime change and multi-scalarity. In a nutshell, CAS thinking is avoiding controlling agricultural systems but designing practices and solutions that are place and context specific.

However, presence of integrated system management approach is not enough to conclude that there is CAS thinking because there may be other reasons. For instance, one farmer in the OSN stated "…I have seen others do it and seen others quit, so I was curious; The economics looks favourable; Cover crop was important to start nutrient cycling with the compost addition; Double banding should save money and boost performance ...and it more closely follows 4R guidelines". The rationale for adopting BMPs can vary considerably even with an individual. Actor S indicates such variation for adopting only one BMP. Therefore, even when multiple BMP practices were being used by OSN farmers, the rationale for using them did not show CAS thinking nor an understanding that agroecosystems systems are dynamic and unpredictable.

Furthermore, though OSN farmers did not demonstrate CAS thinking, their thoughts were more towards environmental stewardship which influences BMP adoption. Liu et al. (2018) review of literature on factors influencing adoption of BMPs shows a positive and significant relationship between farmer's environmental consciousness in the forms of awareness of water

quality and environmental stewardships, and BMP adoption. Examples of rationale include "build organic matter, keep soil in field", "Improves soil health, saves time/money, better water infiltration". Farmers are managers and low-level agents of agricultural systems but their thinking pattern influence resilience (Gardner, 2019), even when it may not clearly seem to foster CAS thinking. Cognition is demonstrated in actions. FNs can help create CAS thinking if there are deliberate efforts and reduce subjectivity, so that actions are based on knowledge not just feelings. This is because, it indirectly influences the resilience of SES (soil) via changes to thinking on decisions and management processes (Bohensky et al. 2015).

The participation of actors across all relevant disciplines and sectors related to agriculture is a principle aimed at ensuring resilience of the system (Leitch et al. 2015). This also implies active engagement of network and group members in the relevant sector activities including market, government. Most members of OSN belong to of farmer association and have engaged at individual capacity with different actors in the sector. At the network level however, participation appears to be weak, perhaps since it a relatively new network but participation can be strengthened. OSN is involved with provincial department of agriculture in developing a soil strategy. And this is a relevant engagement and a good starting point but there is room to improve because experiential knowledge of farmers is fundamental together with science for development of agricultural policy (Main & Van Dijk, 2017).

Participation builds trust and relationships, legitimacy of knowledge base and decisions (Leitch et al. 2015). The EU Hennovation project was a success because of multiactor (farmer-led networks, market-driven actors, industry, researchers, veterenians) participation in designing a more sustainable hen laying sector (European Union, 2017). The researchers through this project learnt to trust farmers to intiate research process by determining practial problems they wanted

addressed and so did other actors build trust in the process. Also, actor participation contributes to strengthening the link between information-gathering and decision-making (Danielsen, Burgess, & Balmford, 2005). Through the Hennovation project, the UK, Sweden have decided to allow farmer-led networks to be at the centre of innovation and research projects, and policy in egg production sector. For the OSN, it can contribute to strengtheneing the link between information gathering and decision-making for soil management. For example, OSN have been involved in the provincial soil strategy process. Farmer traditional knowledge and experience are valuable input on how to effectively manage the soil. The network has prospects and can engage more in future sector decision making processes.

5.7 Effectiveness of OSN – Next Steps

Resilience of agricultural systems as SES is complex and perhaps an ambitious goal. But this can be achieved by using multiscalar approach to address it different scales simultaneously. One way is considering the effectiveness of FNs particularly as it has been shown in previous section the effects of farmer network structure and its function on resilience of SES. However, this is approached with caution because it varies with scale of analysis (Lebel, Grothmann, & Siebenhüner, 2010).

First, OSN needs to expand its network to a multi-actor-based network. It is understandable that now there is collaboration with researchers and institutions on some support functions. But a more diverse composition to include partnerships with various stakeholders including professional (Pape & Prokopy, 2017) will be beneficial. Findings from this study show that some actors are speaking with wide range of professionals such as crop advisors. Heterogeneity of actors brings different perspectives and it encourages resilience (Gardner, Ramsden, & Hails, 2019). An example of how to increase effectiveness of ties is converting weak ties between network and

researchers and universities to support formation of FNs (Manson, Jordan, Nelson, & Brummel, 2016). This suggestion was derived from farmer interviews surveyed for modelling adoption of rotational grazing in grazing networks. The organizational chart of OSN indicates collaboration with researchers and other relevant sector stakeholders (Rural Ontario Institute, 2019). But they are on the soil network advisory team and it is unclear the extent of their involvement in the network. However, the reach can be expanded to create wider variety. In addition to diversifying actors, Pape & Prokopy, (2017) suggest that more farmers in a network increases chances of effectiveness but there were no specifics on maximum number. This is particularly relevant for a network designed around diffusion. The number of participants for the yearly program should be increased for greater impact. This may come with increased cost. There are currently no caps on the maximum number of participants, and it is open to all farmers but a better way of reaching out to achieve diversity will be useful.

Second, actor communications and interactions in general need to be strengthened to increase chances of adoption and its core objective of BMP diffusion. Meetings are not the only form for interactions. There is room to explore use of internet platforms and social media to interact including webinars and workshops. This removes the geographical barrier, studies have shown that where farmer networks onboarded these alternatives and technology, communications improved significantly (Skaalsveen et al. 2020). Also, interactions can be negatively influenced within the OSN with the approach used which is mainly diffusion. It is more external extension focused service to other farmers than the network members themselves. In addition, based on the interactions within the network, it does not appear that social learning is deliberately explored within the OSN.

Third, another factor that can hinder effectiveness of network function is the length of time in a network. Studies show that longer duration in a network has positive influence on adoption rate (Pape & Prokopy, 2017). The longer the duration of being in the network, the higher the adoption rate. It can be inferred from this network that a community of practice is formed yearly with a sole aim of reaching other farmers to adopt soil BMPs with little mechanisms to perpetuate adoption within the network itself. The retention rate indicates that more needs to be done to strengthen the network beyond the yearly program. In addition, there is need to keep track on how many people that have been reached so far by the early adopters. And very importantly, to know the type of farmers and other actors reached. For instance, Pape & Prokopy, (2017) discovered that diffusion outside the network was not effective because farmers were speaking with farmers who were already using the diffused nutrient management practices.

Finally, there is an urgent need to increase access to funding for FNs. The Hennovation project of the EU demonstrated the importance of supporting FNs to access funds (Main & Van Dijk, 2017). The contribution of FNs is so crucial to development of the entire agricultural sector because their experiential knowledge sometimes couples with intergenerational knowledge (for those from a lineage of farmers) is invaluable for innovation (Lengnick, 2015a). In addition, they constitute the major end users of innovations from the traditional linear extension model (scientist to farmers) and they need funds for trials as groups then as individuals. Therefore, for the OSN, as the network continues to evolve, there is need to decide the most suitable funding model to sustain it.

6.0 LIMITATIONS OF STUDY

Like every other research, this study was conducted with some limitations in mind and some were observed at a later stage and it is noted as follows. First, determining the most appropriate surrogates for each resilience principle was challenging considering that resilience is a complex term with variations in time and space. For instance, the relationship between connectivity and resilience is indirect and complex too (Dakos et al. 2015). This is because of the multiscalar nature of resilience operating simultaneously at these levels e.g. actor/farm level and at the network level. This affected how the survey questions were framed and perhaps questions did not exactly yield the most useful evidence.

Secondly, it would have been helpful to survey factors and not just reasons for non-adoption of BMPs. This would have helped in comparing with several reviews on these factors (Liu et al. 2018). Thirdly, complete networks approach is beneficial mainly for understanding the whole network structure and identifying key players. But perhaps considering the ego-networks of the key players would have given more insights about the network structure and functions. Fourthly, actor attributes would have helped answer the question on heterogeneity and how it influences resilience but this was not covered in the study. So no conclusion can be made on this function.

7.0 CONCLUSION

The literature on the role of social networks in enhancing natural resources management and governance is common. Farmer networks have been extensively studied in areas furthering agricultural extension initiatives such as innovation and new technology adoption. But not much has been done in understanding how farmer network structure and function can influence adoption of soil BMPs, and notably its prospects to foster a resilient agriculture. This is novel to the literature on farmer networks. An empirical approach was used with a FN as a case study. This was informed on a conceptual framework of agricultural systems as socioecological systems. FNs represent part of the sociological systems while soils represent part of the ecological system and BMPs as one of the appraoaches of sustainable agriculture Four principles that foster the resilience of ecosystem services were used to assess if FNs structure and function helps in fostering these principles.

The main findings of this study are that a well-connected diffusion FNs does not only have effects on diffusion outside the network but also has a positive effect on adoption within the network. Majority of actors adopted more than one soil BMP. This is attributable to social interactions within the network and it is an indirect form of diffusion. FNs are alternatives to using the conventional linear method of diffusion from experts, scientists to farmers. Social analysis of this network has shown positions of key players and their potential roles.

Secondly, periphery actors were more involved in connecting with actors outside the network compared to the core actors. This occurrence is interesting because it means that periphery actors may not need to depend entirely on core actors to take initiatives in innovation and diffusion. Hence, they do play relevant role in the network too.

Thirdly, there is a positive correlation between frequency of communication among actors and change in production system or adoption of BMPs. The more frequently an actor communicates with other actors, the greater the chances of adoption of BMPs. However, frequency of communication does not always guarantee adoption but the quality of communication amongst other factors also influence adoption. For quality, the content of what is communicated (e.g. farming conversation), and how actors perceive the communication (positive or negative; giving or receiving advice or mutual) are equally important.

Fourthly, FNs demonstrated contribution to resilience based on two principles (manage connectivity and encourage learning and experimentation). FNs have been shown to influence governance opportunities at various levels (Dakos et al. 2015) through both resilience principles of connectivity and encouraging learning and experimentation. FNs create an atmosphere for innovation with their experience as basis of experimenting, learning and trying new ways out. FNs is a safe space for scaling up adoption of pro-environmental farming practices, but it must be managed in a way that natural resources are not over exploited.

The principle of broadening participation was partly met. FNs did not satisfy the principle of fostering an understanding of CAS thinking. OSN farmers however showed some thinking towards environmental awareness and stewardship. At the collective level, principle of connectivity was evidently satisfied as indicated by network structure and flow of information in the network. This contributes to the general resilience of agricultural systems. And so was the principle of encouraging learning and experimentation. Broadening participation at the network level was partly satisfied with evidence of some level of participation by the network in soil strategy in the province.

The wider implications of FNs on BMP adoption are the ecological, economic and social benefits. Soil BMPs, apart from reducing non-point source pollution of surface and groundwater, also encourage water conservation, soil erosion control and contribute to the overall ecosystem health. This contributes in enabling the adaptive capacity of the soil as SES and the overall agroecosystem to bounce back and even bounce forward (transform) if necessary, with perturbations. Agroecosystems that are resilient are adaptive to support food production and supply in general for our increasingly growing population. However, there is need for policy interventions in improving the operating context.. Farmer networks need to be supported financially and otherwise to encourage innovation and diffusion of BMPs. Given the low to medium range uptake of BMPs in Canada, FNs can be useful in increasing the scale and scope of adoption by encouraging establishment of FNs by legitimate farmers who are already using some BMPs. And in the process of diffusion, they can learn new practices and/or modify existing practises. This will improve overall extension structure in the province. In concluding, FNs structure can influence BMP adoption by the speed and ease of information flow through communication channels. Also, the transmission of quality, experiential and/or local knowledge in a form easily understood by farmers is higher through FNs. This confers some level of relevance because as studies have shown, farmers prefer the information relevant than roles.

From this study, future research considerations have emerged. there is need to keep track on how many people that have been reached so far by the early adopters. And very importantly, is to know the type of farmers and other actors reached. For instance, Pape & Prokopy, (2017) discovered that diffusion outside the network was not effective because farmers were speaking with farmers who were already using the diffused nutrient management practices. Also, there is need to understand the role of social media in influencing BMP adoption. Also, there is need to

look at diversity of actors and how it influences quality of communication. A multiactor farmer network increases the efficiency as shown in earlier section. In addition, since meetings are non-mandatory and the number of meetings annually not fixed, then it will be helpful to determine the mechanisms of networking which was not considered in this study. Is it face-to-face, social media, forums, farmer events, telephone, etc. This is important in improving the prospects of frequency and quality of communication and building trust particularly where they are geographically dispersed. This also highlights the role of technology in facilitating communication and interactions. Finally, are there any innovations occurring within the network (OSN)? It is important to determine if innovations occur because the focus on diffusion may mask innovation happening in the network or their innovative potentials at large.

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9.0 Appendices

9.1 Appendix A - Email survey Questionnaire

Questionnaire for the Ontario Soil Network

Q1 Please provide your full name (first and last name) in the space below:

_____

Q2 How many meetings of the OSN have you attended: (open)

_____

Q3
In what ways are you involved in your local community (choose all that apply)?

- ☐ Farm association
- ☐ Community service
- ☐ Church/religious activities
- ☐ Informal neighbourhood group
- ☐ Other (please specify) _____
- ☐ I am not involved with my local community

Q4 How happy are you with the soil health management practices you have implemented in the past? (Choose one)

- Very happy
- Happy
- Neither happy nor unhappy
- Unhappy
- Very unhappy

Q5 Since joining the Ontario Soil Network, have you adopted any of the following soil health management practices on your land? Check all that apply.

- ☐ Cover crops
- ☐ Strip till / no till
- ☐ Manure / compost/ other amendments
- ☐ Crop rotation
- ☐ Windbreaks
- ☐ Erosion control structures
- ☐ Other 1 (please describe): _____
- ☐ Other 2 (please describe): _____

Carry Forward Selected Choices from "Q12"

Q6 If you selected "other" as an option in the list above for one or more management practices, please provide a bit more information below.

_____

Carry Forward Selected Choices from "Q13"

Q7 What is the PRIMARY reason for why you decided to use each of the following management practices? Please select only ONE option. *(Note that only items selected in Q12 are displayed)*

	I was concerned about erosion	It was better for my farm	It saved me money	I saw other farmers doing it	I thought it was the right thing to do	It was subsidized or paid for	Other
Cover crops	○	○	○	○	○	○	○
Strip till / no till	○	○	○	○	○	○	○
Manure / compost/ other amendments	○	○	○	○	○	○	○
Crop rotation	○	○	○	○	○	○	○
Windbreaks	○	○	○	○	○	○	○
Erosion control structures	○	○	○	○	○	○	○
Other 1 (please describe):	○	○	○	○	○	○	○
Other 2 (please describe):	○	○	○	○	○	○	○

Q8 If you selected "other" as an option in the dropdown list above for one or more management practices, please provide a bit more information below.

_____

Q9Please provide UP TO THREE additional reasons for why you have implemented the following management practices:

_____

Q10	Please answer the following questions *Since joining the OSN:*																
	how often do you communicate with this person?						Do you speak with this person about farming?			What is the nature of your communications with this person?				Are your communications generally positive, negative, or neither (neutral)?		
	Daily	Weekly	Monthly	Seasonally	Yearly	Less than once per year	Often	Sometimes	No	They mostly ask for advice from me	I mostly ask for advice from them	It's mutual	We don't share information or advice	Positive	Negative	Neutral
Farmer A	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Farmer B	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Farmer C	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Farmer D	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Farmer E	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Farmer F	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

Farmer G	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Farmer H	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Farmer I	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

Carry Forward Unselected Choices from "Q23"

Q11 Please answer each question for the following farmers *(Note that only farmers who they indicated they know/have spoken with in Q23 are displayed)*

	Since joining the OSN, have you made a production system change as a result of your communication with this person?	
	Yes	No
Farmer A	○	○
Farmer B	○	○
Farmer C	○	○
Farmer D	○	○
Farmer E	○	○
Farmer F	○	○
Farmer G	○	○
Farmer H	○	○
Farmer I	○	○
Farmer J	○	○

Page Break

Q11 Is there a farmer or farmers who you look up to within the OSN? If so, please identify them and provide a short explanation of why. (Open question)

Q12 Since joining the OSN, who from OUTSIDE the OSN has influenced your decisions about your farm? Please list up to 10 people (Farmers or others) in the far left column, and then answer the following questions:

	How often have you communicated with this individual?						Have you made a production system change as a result of this individual's influence?	
	Daily	Weekly	Monthly	Seasonally	Annually	Less than once per year	Yes	No

Person 1	○	○	○	○	○	○	○	○
Person 2	○	○	○	○	○	○	○	○
Person 3	○	○	○	○	○	○	○	○
Person 4	○	○	○	○	○	○	○	○
Person 5	○	○	○	○	○	○	○	○
Person 6	○	○	○	○	○	○	○	○
Person 7	○	○	○	○	○	○	○	○
Person 8	○	○	○	○	○	○	○	○
Person 9	○	○	○	○	○	○	○	○
Person 10	○	○	○	○	○	○	○	○

Page Break

Q13 Since joining the OSN, who from OUTSIDE of the OSN have you influenced regarding farming decisions? Please list up to 10 people (Farmers or others) in the far left column, and then answer the following question:

	How often did you communicate with this individual since joining the OSN?					
	Daily	Weekly	Monthly	Seasonally	Annually	Less than once per year
Person 1	○	○	○	○	○	○
Person 2	○	○	○	○	○	○
Person 3	○	○	○	○	○	○
Person 4	○	○	○	○	○	○
Person 5	○	○	○	○	○	○
Person 6	○	○	○	○	○	○
Person 7	○	○	○	○	○	○
Person 8	○	○	○	○	○	○
Person 9	○	○	○	○	○	○
Person 10	○	○	○	○	○	○

Q14 Since joining the OSN, are there any new or different sources you turn to related to soil health and management practices? (e.g., farmer associations, government agencies, crop advisors, etc.)? If so, please list up to 10 in order of importance and answer the following questions.

	What kind of information or assistance do you primarily obtain from this source (i.e., topic)?	Did you make a change to your production system as a result of this source?	
	Topic	Yes	No
Source 1		○	○
Source 2		○	○
Source 3		○	○
Source 4		○	○
Source 5		○	○
Source 6		○	○
Source 7		○	○
Source 8		○	○
Source 9		○	○
Source 10		○	○

9.2 Appendix B - Interview Script

Questions

1. When was OSN formed?
2. Why was it formed? – prompt: and how?
3. Are members of the network actively engaged as relevant stakeholders in projects/decision-making of government agencies, other relevant organizations? E.g. public hearings or any government feedback process? Are there any examples?
4. Why is it called a farmer-led network?
5. What is your role in OSN?
6. Would you consider it a formal or informal farmer network?
7. Is OSN (organizational level) involved in decision-making/opinion forming/ policy/ lobbying with other organization - government, NGOs, input and/or service companies? If yes, what are the examples?
8. How many times in a year does OSN hold meetings? Is attendance obligatory?
9. Can you throw more light on the 1year early adopter program? – prompt: are graduates still part of the network? Criteria for selection.
10. Is membership open to all farmers in Ontario?